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Cumulative discard methodology review for catch cap monitoring in the Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*) fisheries

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A working paper in support of the Cumulative Discard Methodology Peer Review

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Background

The Atlantic herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*) fisheries operate under the restrictions of seven total catch caps designed to limit the amount of incidental catch of haddock (*Melanogrammus aeglefinus*) and River Herring/Shad (RHS), which is composed of alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), and hickory shad (*Alosa mediocris*). If a catch cap is reached, Accountability Measures (AM) go into effect and restrict fishing within each catch cap area.

The Atlantic herring fishery currently has six catch caps arrayed by catch cap species, gear and area (figure 1): (1) Haddock : Georges Bank (GB) Midwater Trawl, (2) Haddock: Gulf of Maine (GOM) Midwater Trawl, (3) RHS: Cape Cod (CC) Midwater Trawl, (4) RHS: GOM Midwater Trawl, (5) RHS: Southern New England (SNE) Bottom Trawl, and (6) SNE Midwater Trawl. The current GB and GOM haddock catch caps were implemented through Groundfish Framework 46 in fishing year 2011, which separated the previous existing haddock catch cap into separate GB and GOM stock areas and adjusted the estimation methodology to the current extrapolation method. Herring Framework Adjustment 3 set RHS catch caps for 2014-2015 and was implemented on December 4, 2014 with the first complete implementation year in 2015. The haddock catch caps operate on a May-April fishing year, while the RHS catch caps operate on a January-December fishing year. For RHS catch caps, trips landing greater than 6,600 pounds of herring are counted against an individual catch cap depending on the gear and area of the trip. For haddock catch caps, midwater trawl trips in GB and GOM are counted against the catch caps; there is no 6,600 herring landings threshold for inclusion in the haddock catch caps.

The Atlantic mackerel fishery currently has a single RHS catch cap that covers all trips landing greater than 20,000 pounds of mackerel regardless of gear or area. Squid, Mackerel, Butterfish Amendment 14 set RHS catch caps for 2014-2015 and was implemented on April 4, 2014 and effective for all of fishing year 2014 (January-December).

Annual haddock catch caps are set by the Multispecies Fisheries Management Plan (FMP) and are a function of the size of the haddock resource and will fluctuate up and down with the overall haddock Acceptable Biological Catch (ABC) for a given year. Contrary to haddock, RHS catch caps are not biologically based, rather they are set according to historical RHS catch. RHS caps are set during the multiyear specifications process in the Atlantic herring and Squid, Mackerel, Butterfish FMPs.

The herring and mackerel fisheries are primarily high volume fisheries where midwater trawl gear produces the majority of landings, however bottom trawl and purse seine gear types also contribute to landings in these fisheries. Both fisheries are constrained by Annual Catch Limits (ACL), the mackerel fishery has a single stock-wide ACL, while the herring fishery's ACL is divided into area specific sub-ACLs (figure 1). The herring fishery has harvested more than 90% of its ACL in two of the last three years (NOAA, 2016a), while the mackerel fishery has been more variable and only harvested 26% or less of its ACL (NOAA, 2016b). Both fisheries operate year round, but recently the mackerel fishery has been primarily prosecuted during the winter and spring. The herring fishery exhibits a spatial-temporal effort pattern where it seasonally concentrates in specific areas. The herring purse seine fishery is generally a summer and fall fishery that is exclusive to the GOM. Recently, the herring midwater trawl fishery has primarily operated on GB from spring through early fall, with brief activity in GOM in the fall before shifting to SNE during the winter months. The bottom trawl fishery primarily occurs in SNE in the winter.

Total catch in each catch cap is a function of the underlying fishery operating within it, and is driven by two components: (1) total fleet landings and the (2) incidental catch rate. Catch cap estimation is sensitive to either component. If the fishery underlying a catch cap is operating at low intensity, than the catch estimate in that catch cap will likely be low as well. This dynamic is exemplified by the mackerel fishery, which has operated at a relatively low intensity over the past few years and yielded RHS catch estimates below 15% of the catch cap (NOAA 2016c). Conversely, the herring fishery has been operating at normal intensity over the last few years producing more variable catch cap estimates that resulted in overages in the GB haddock and RHS SNE bottom trawl catch caps in 2015 (NOAA 2016d, 2016e).

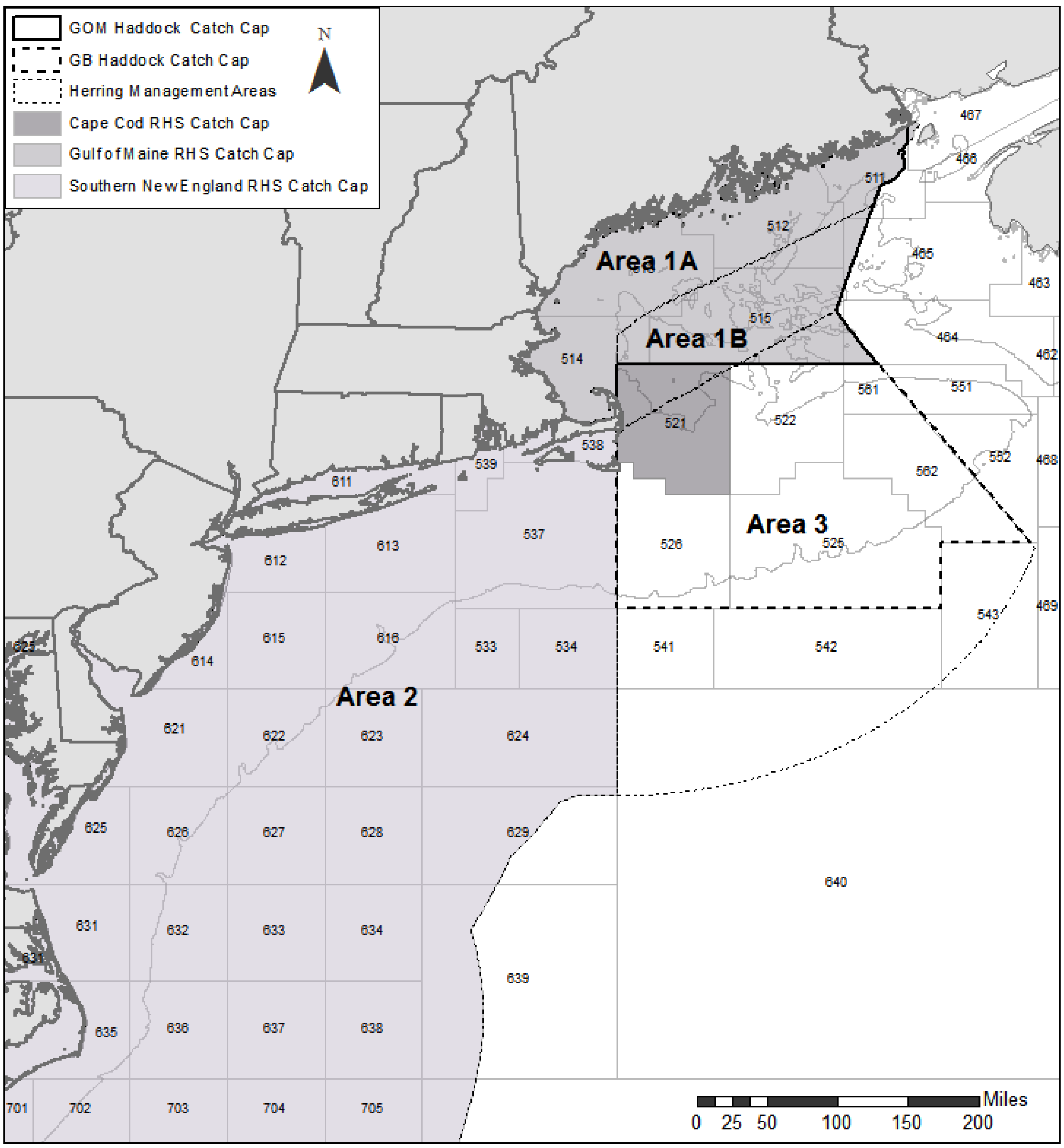

Figure 1. Atlantic herring River Herring/Shad (RHS) and haddock catch cap, and herring management areas

Catch cap estimates in these fisheries are comprised of both incidental kept and discard components to generate a combined incidental catch estimate. Current quota monitoring methodology for these catch caps employs the annual separate ratio estimator (equation 1) derived from Northeast Fisheries Observer Program (NEFOP) observer data to extrapolate incidental catch (equation 2) to the fleet (Palmer 2010). This method is commonly referred to as the cumulative method.

(1)

$$r_{jh} = \frac{\sum_{i=1}^{n_h} c_{jih}}{\sum_{i=1}^{n_h} k_{ih}}$$

(2)

$$\hat{C}_j = \sum_{h=1}^{L} K_h r_{jh}$$

Where:
$\hat{C}_j$ is the total estimated incidental catch in pounds of catch cap species *j*;
K_h is the total kept pounds of all species on catch cap trips in stratum *h*;
r_{jh} is the observed incidental catch rate of catch cap species *j* in stratum *h*;
c_{jih} is the observed kept and discard of catch cap species *j* on observed trip *i* in stratum *h*;
k_{ih} is the observed kept pounds of all species on observed trip *i* in stratum *h*;
L is the number of strata;

Only observed trips are used to derive the ratio estimator, which is unstratified within each catch cap. The ratio estimator is continuously updated throughout the fishing year and retroactively applied to cumulative fleet kept all (KALL). KALL is obtained from integrated Vessel Trip Reports (VTR) and dealer data, which provide effort information (gear and area) and landings information respectively. Actual observed incidental catch amounts are used in lieu of estimated incidental catch amounts whenever possible, which means that actual incidental catch values are used to replace estimated values. This is commonly referred to as the replacement methodology. A transition method is applied when there are not enough observed trips from the current fishing year (in-season) to reliably estimate the incidental catch for a specific catch cap. If fewer than five trips are available from the current fishing year, the ratio estimator from the prior fishing year is used as the assumed catch rate, with increasing weight placed on the in-season rate as more data become available. After five trips occur, transition to the in-season data is complete and are used for the remainder of the year. The formula for the transition rate is:

(3)

$$r_{t,jh} = \left(\frac{0.7}{n_h}\right) r_{a,jh} + \left(1 - \left(\frac{0.7}{n_h}\right)\right) r_{i,jh} \quad , n_h\ from\ 1\ to\ n_{max,h}$$

Where:
$r_{t,jh}$ is the transition rate for species j in stratum h;
$n_{max,h}$ is the maximum number of in-season observed trips in the transition period for stratum h;
n_h is the total observed catch cap trips in stratum h;

$r_{a,jh}$ assumed rate derived from prior period incidental catch rate of catch cap species j in stratum h;
$r_{a,jh}$ in-season rate derived from current period incidental catch rate of catch cap species j in stratum h;

Methods

Only fishing years when catch caps were implemented were included in the analysis. The haddock catch cap analysis includes 2011-2015 and the RHS catch cap analysis includes 2014-2015 fishing years. The same data sources and methods used for quota monitoring were applied to this analysis in order to construct alternative sub-stratifications within each catch cap. The performance of alternative stratifications were measured in terms incidental catch estimation precision, and compared under two different transition rate regimes. To evaluate the stability of the each stratification and transition rate, the daily point estimate of incidental catch was modelled with a bootstrap approach. Aside from the bootstrap, the only other methodological divergence between this analysis and operational quota monitoring is the absence of the replacement methodology. The replacement methodology was not employed in this analysis because of the complications it posed for simulation and precision calculation. The effect of this methodological difference should have a negligible impact on the outcomes of the analysis.

The coefficient of variation (CV) (equation 5) was used to quantify the precision of the estimated catch and was derived from the variance of the incidental catch estimate (equation 4).

(4)

$$V(\hat{C}_j) = \sum_{h=1}^{L} K_h^2 \left(\frac{N_h - n_h}{N_h n_h}\right) \frac{1}{\left(\frac{\sum_{i=1}^{n_h} k_{ih}}{n_h}\right)} \left[\frac{\sum_{i=1}^{n_h} \left(c_{jih}^2 + \left(r_{jh}\right)^2 k_{ih}^2 - 2 r_{jh} c_{jih} k_{ih}\right)}{n_h}\right]$$

(5)

$$CV(\hat{C}_j) = \frac{\sqrt{V(\hat{C}_j)}}{\hat{C}_j}$$

The CV is sensitive to sample size. In a finite population the CV will converge to zero as the sample size approaches the population size. The total fishing trips within a stratum is considered finite, therefore as sampling coverage approaches 100%, the CV will converge to zero for that stratum. The CV analysis follows the guidelines detailed by the Standardized Bycatch Reporting Methodology (SBRM) and uses the trip as the sampling unit (Wigley et al., 2007). Only observed trips (trips w/at least one observed haul) and trips reporting kept catch on their Vessel Trip Report (VTR) were used in the CV analysis. This distinction is important to understand when interpreting observer coverage rates (referred to below as “realized” observer coverage) because in the midwater pair-trawl fishery it is not uncommon for wing vessels to be covered by observers and not take on any catch. These trips would not be reflected in the observer coverage rates described in this analysis.

Incidental catch estimation in the catch cap fisheries requires analogous data elements in both the NEFOP observer and VTR data collections in order to extrapolate the correct fleet KALL (VTR) by the correct ratio estimator (observer data). Due to this requirement, alternative stratification options were limited to measureable strata that could feasibly be defined by data elements common to both the observer and VTR data collections. Five broad stratification categories were evaluated: (1) temporal, (2) gear, (3) area, (4) vessel category, and (5) trip landings category. Multiple permutations and/or combinations of these classes produce numerous stratifications resulting in high dimensional data. However, the overall practical range of stratification options is constrained by the rather narrow management definitions of each catch cap that are specific to certain areas, gears, and/or landing thresholds. Furthermore, the number of available samples (i.e. observed trips) within each stratification is also limiting. Data dimensionality was further reduced by manually evaluating distributions of trips and KALL by stratification class to identify critical breaks. This was supported by iterating through all potential break points within a class, splitting by that break point, and calculating the CV in order to identify the break point that yielded the lowest CV. The output of this process was an initial set of stratification options for each catch cap.

These initial stratification categories were further refined by performing a bootstrap analysis of the ratio estimator within each stratum and comparing the resulting distribution from the stratification option to the overall distribution for the catch cap baseline (default stratification). Strata options that yielded divergent ratio estimators suggest meaningful potential stratifications. The bootstrap analysis was performed on all years of observer data pooled together in order to maximize sample size and identify broad trends in the data. The initial stratifications were also screened by comparing their combined CV to the baseline catch cap CV for each individual fishing year. Stratification options that exhibited divergent ratio estimators and showed gains in CV performance were identified as candidates for analysis with the bootstrap model developed within the discaRd package (Galuardi et al., 2016) for the statistical software R (R Core Team, 2015).

The bootstrap model evaluated each stratification candidate by resampling (n=1000) the weekly point estimate of incidental catch for each fishing year when a catch cap was effective. The bootstrap accounted for two different transition rate applications (separate runs): (1) the baseline five trip transition rate currently employed (equation 3) and (2) a moving window option that used observed trips from the prior period as a proxy for expected observed trips (Linden et al., 2016). For example, in an annual stratification scheme, the point estimate ratio estimator six months into the current fishing year would be constructed from observed trips from the first six months of that fishing year and observed trips from the last six months of the prior fishing year. The bootstrap results of each simulation produced both weekly median catch cap point estimates as well and quantiles around the median estimate to describe estimation uncertainty. The terminal point estimate (last day) of the year represents the final year end catch cap catch for each simulation.

Probabilities of exceeding a catch cap were produced from the bootstrap model output by calculating the proportion of bootstrap iterations (n=1000) that exceeded the catch cap for each week. The first day in the fishing year that produced a $P>0$ and a $P>0.5$ were identified for each bootstrap model to describe risks of premature closure. The probability of the terminal estimate exceeding the cap P(>Cap) was calculated in a similar manner. Differences between the median terminal day bootstrap catch estimate and the extrapolated quota monitoring (QM) estimate (Median-QM) were also calculated.

Results: Atlantic Herring Fishery

Baseline (regulatory defined stratification) analyses were performed on all herring catch caps. However, due to varying dynamics between catch caps, different analytical approaches were applied. The GOM haddock catch cap had an incidental catch rates of zero for fishing years 2011-2015 precluding any analysis. Alternative stratifications and bootstrap model runs were evaluated for GB haddock for all effective fishing years 2011-2015. Through analysis of the herring RHS catch caps was hindered by small sample size because only one complete year (2015) of data exists.   In an effort to increase sample size and increase information, 2014 (full year) data were included in the RHS cap analyses despite being a partial implementation year. Additionally, the amount of observer coverage within the baseline RHS stratifications is already limited, with coverage rates as low as 2.3% (table 1). Further stratification of these already data poor cells would exacerbate the issue and further reduce sample size and analysis quality. Despite these limitations, the more heterogeneous fleet within the RHS SNE bottom trawl catch cap coupled with its higher relative observer coverage warranted a coarse analysis of potential stratifications in this catch cap only. Alternative stratifications were not evaluated for RHS SNE, GOM and CC midwater catch caps due to their narrow baseline stratifications and/or low observer coverage. RHS CC midwater is constrained to a single statistical area, and the majority of effort in RHS GOM midwater occurs during a very discrete period in the fall, and RHS SNE midwater had too little observer data available for analysis. Baseline bootstrap model runs were completed for all RHS herring catch caps. More comprehensive analysis of herring RHS catch caps may be possible in the future, but will still be limited by the narrow manner in which these catch caps are specified in regulation.

The baseline CV and observer coverage rates for the haddock and RHS catch caps for the years they were effective are detailed in table 1. The relationship between observer coverage and the CV is described in figure 2, the realized CV and observer coverage for each year is indicated with a black dot.

Table 1. Atlantic herring fishery realized haddock and RHS catch cap CV and observer coverage (in parentheses), 2011-2015

	Fishing Year[1]: CV (Observer Coverage)				
Catch Cap Fishery	**2011**	**2012**	**2013**	**2014**	**2015**
Haddock: GB Midwater Trawl	17.6% *(41.7%)*	12.3% *(62.9%)*	21.3% (35.6%)	20.5% *(27.2%)*	61.4% *(4.9%)***
Haddock: GOM Midwater Trawl	0.0% *(30.4%)*	0.0% *(29.2%)*	0.0% (34.8%)	0.0% *(46.3%)*	0.0% *(8.6%)*
RHS: CC Midwater Trawl				36.2% *(48.0%)**	81.4% *(10.1%)*
RHS: GOM Midwater Trawl				37.3% *(50.0%)**	94.8% *(8.7%)*
RHS: SNE Bottom Trawl				28.4% *(17.4%)**	24.5% *(15.0%)*
RHS: SNE Midwater Trawl				70.2% *(3.4%)**	11.8% *(2.3%)*

Source: GARFO Quota Monitoring Database as of 5/22/2016
[1]Catch cap fishing year: river herring/shad = calendar year; haddock = May-April
*2014 Herring RHS fishing year partially covered by RHS Catch Caps which was implemented on December, 4 2014
**2015 GB Haddock fishing year truncated due to the closure of the GB Haddock AM Area on October 22, 2015

The GB haddock and RHS SNE bottom trawl catch caps generally achieve a CV of less than 30% with 25% observer coverage or less. While the remaining RHS catch caps are more variable and require coverage rates of 50% or greater to achieve a 30% CV. GOM haddock yields a CV of 0 for all years because no incidental catch of haddock was observed.

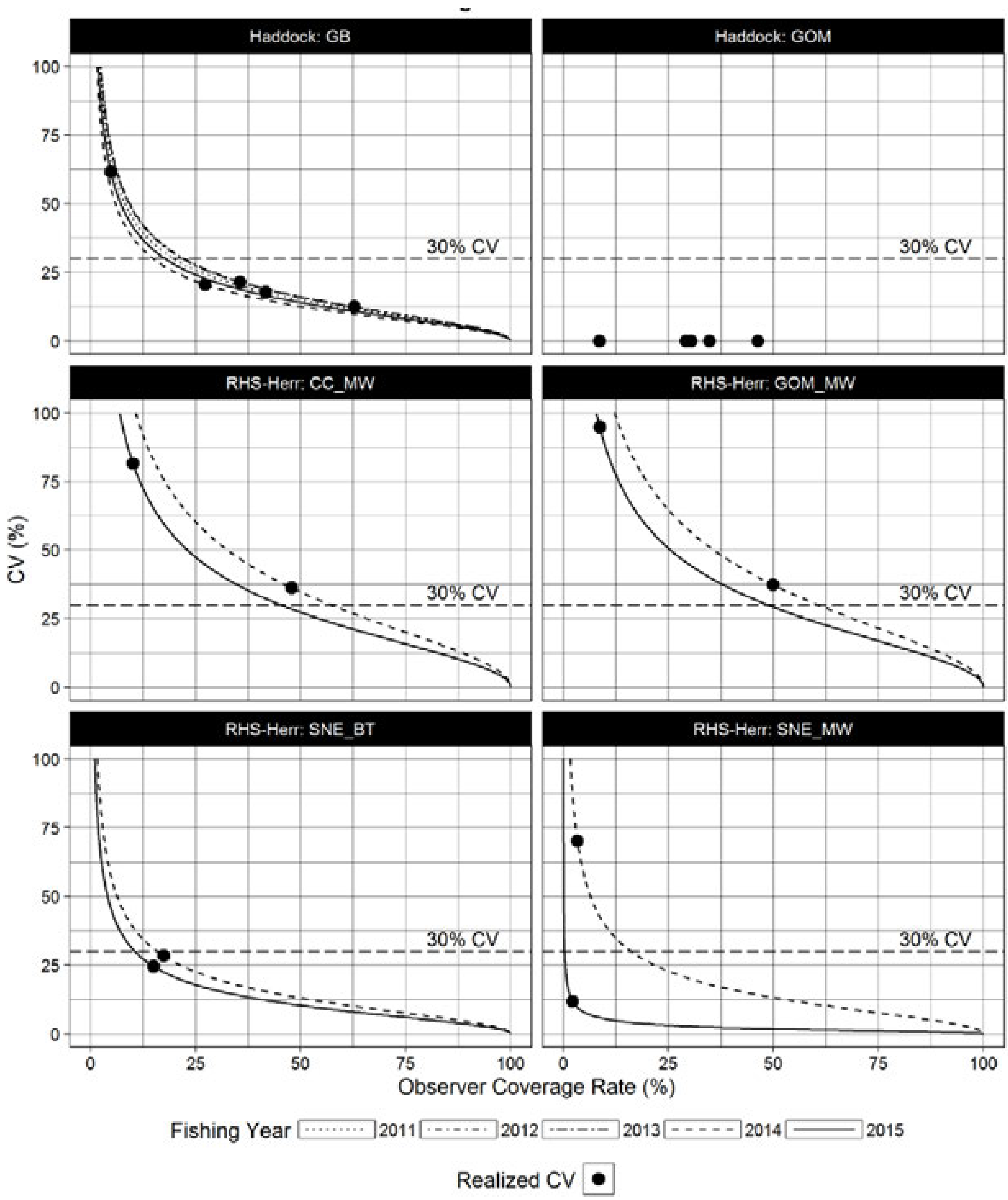

Figure 2. 2011-2015 relationship between observer coverage and estimated CV for each catch cap with realized CV and observer coverage for each catch cap year (black dot)

Stratification Analysis: GB Haddock Catch Cap

Initial GB haddock catch cap stratifications from five broad stratification categories were selected and evaluated (table 2). Temporal stratifications were selected according to several factors. The May-October stratification has been suggested by the herring industry as a possible option and is being evaluated by the herring Plan Development Team (PDT). The quarterly option was selected in response to industry concerns about the retroactive application of the current annual stratification, stratifying by quarter confines any retroactive recalculation of incidental catch to a specific quarter. The May-December stratification was selected to make the GB haddock catch stratifications consistent with the herring fishing year, which operates on the calendar year (January-December). This is a logical choice because catch cap catch is a function of the underlying herring fishery, any management changes (ACL reductions/increases, closures, etc.) and/or effort shifts would likely coincide with the herring fishing year. The selected gear and area stratifications are the lowest resolution stratifications available within the fisheries dependent data sources used for monitoring. Vessel category and trip landings stratifications were selected by visually inspecting and identifying natural breaks in trip distributions.

Table 2. GB haddock catch cap initial stratifications

Stratification Category	Stratification Options
Temporal	Quarterly (May-Jul, Aug-Oct, Nov-Jan, and Feb-Apr) May-October/November-April May-December/December-April
Gear	Single/Paired Midwater Trawl
Area	Statistical Reporting Area
Vessel Category	Less than 120 ft/120 ft and greater
Trip Landings Category	Less than 70,000 lbs/70,000 to 650,000 lbs/greater than 650,000 lbs

Observed trips from fishing years 2011-2014 were pooled together and stratified by the options described in table 2. Fishing year 2015 was omitted because the October 22, 2015 closure truncated the 2015 fishing year preventing representative sampling from the latter half of the fishing year. Bootstrapped ratio estimator distributions (grey histogram) were constructed for each stratification and compared to the overall fishing year 2011-2014 GB haddock ratio estimator distribution (dashed line density plot) (figures 3-5). Three of the seven stratifications evaluated: (1) area, (2) quarterly, and (3) trip landings yielded absolute Z-values greater than two, indicating a substantial divergence between the baseline GB haddock ratio estimator and the stratified ratio estimator.

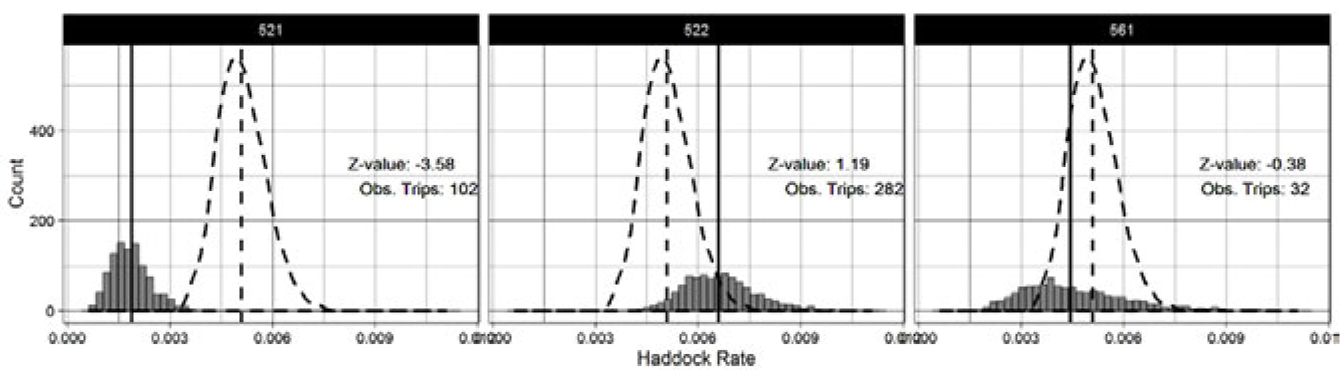

Figure 3. Fishing year 2011-2014 GB haddock catch cap statistical area stratified ratio estimator compared to baseline ratio estimator. Stratified ratio estimator and bootstrapped distribution represented by solid black vertical line and grey histogram. Baseline ratio estimator and bootstrapped distribution represented by dashed vertical line and density plot.

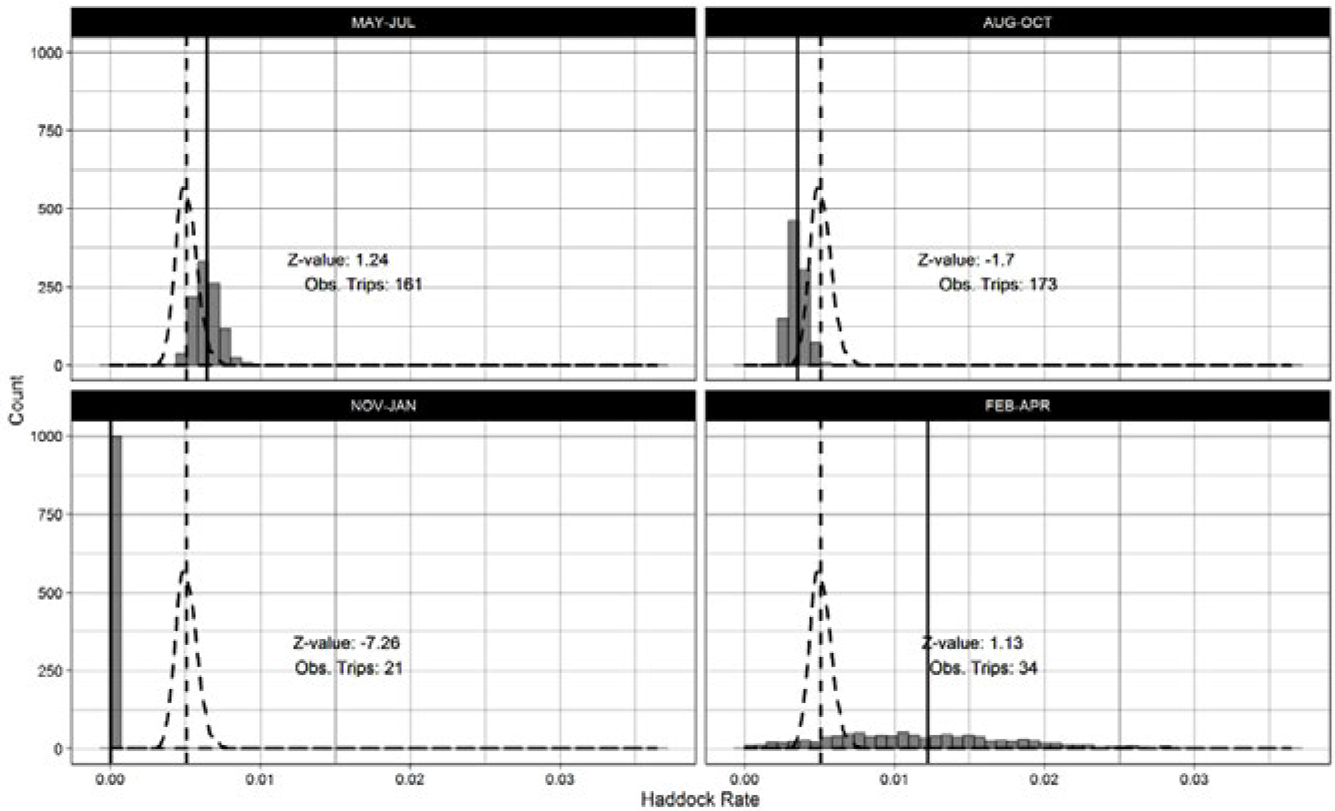

Figure 4. Fishing year 2011-2014 GB haddock catch cap quarterly stratified ratio estimator compared to baseline ratio estimator. Stratified ratio estimator and bootstrapped distribution represented by solid black vertical line and grey histogram. Baseline ratio estimator and bootstrapped distribution represented by dashed vertical line and density plot.

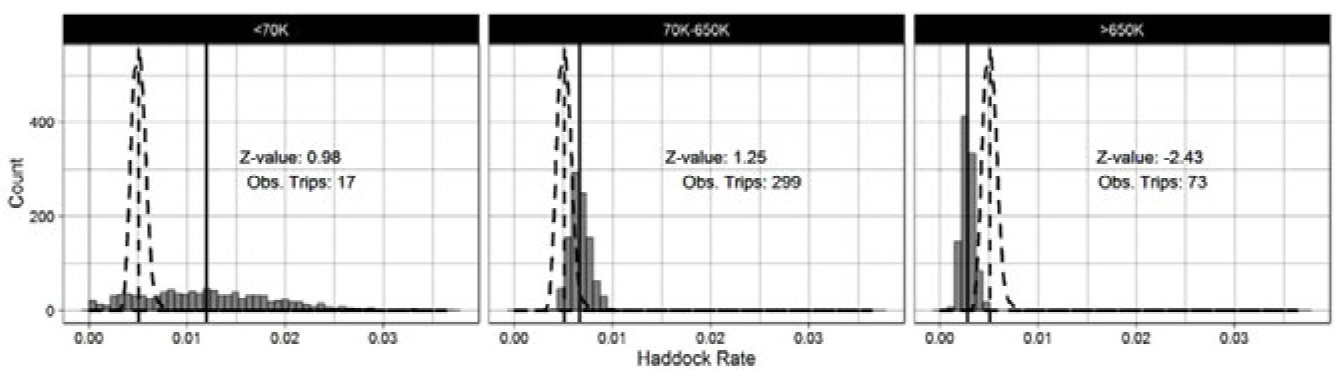

Figure 5. Fishing year 2011-2014 GB haddock catch cap trip landings category stratified ratio estimator compared to baseline ratio estimator. Stratified ratio estimator and bootstrapped distribution represented by solid black vertical line and grey histogram. Baseline ratio estimator and bootstrapped distribution represented by dashed vertical line and density plot.

All initial stratifications were analyzed for CV and haddock estimation performance in each fishing year from 2011 to 2014, and were compared to the baseline CV and haddock estimates for those years. The results were generally mixed, with small aggregate CV improvements over the baseline stratification for all initial stratifications analyzed. The year to year CV differences between the stratified and the baseline comparison were quite variable and better described by the median difference. However, the median tends to mask some of the variability in the temporal stratifications, which showed stratified CV percent change as high as 99%, which is substantially worse than the baseline CV (table 3). Stratifying by statistical area was the best performing initial stratification. It resulted in an improved CV in all of the fishing years and also the largest median improvement in CV. It also did not fluctuate year to year as wildly as the temporal stratification options. The primary weakness of the area based stratification is a low (one observed trip) minimum sample size in on the individual statistical area strata.

Table 3. Initial GB haddock catch cap stratification CV and haddock estimation performance compared to baseline, fishing years 2011-2014

Stratification	# Years CV Improve	Median CV Percent Change	Min CV Percent Change	Max CV Percent Change	Median Est. Haddock Difference (mt)	Min Stratum Observed Trips
May-Oct/Nov-Apr	3	-1.59%	-4.21%	88.28%	0.5	2
May-Dec/Jan-Apr	3	-1.92%	-4.21%	88.28%	0.4	2
Quarterly	3	-2.25%	-6.82%	99.33%	4.9	2
Gear	3	-1.84%	-4.53%	3.53%	-1.2	8
Area	4	-4.67%	-11.36%	-0.50%	2.0	1
Vessel Category	3	-2.06%	-9.21%	1.66%	-1.3	26
Trip Landings Category	3	-2.13%	-3.86%	1.14%	7.2	5

Since the majority of area effect is concentrated in statistical area 522 (figure 3), the area option was condensed to two strata: (1) STAT_522 and (2) OTHER_GB (561 and 521 combined) in order to bolster sample size. The results of combining area with the other stratifications showed incremental improvements beyond those detailed in table 3. However, small sample size becomes a potential issue when applying combination stratifications, with many yielding low minimum stratum observed trips (table 4).

Table 4. Combined GB haddock catch cap stratification CV and haddock estimation performance compared to baseline, fishing years 2011-2014

Stratification	# Years CV Improve	Median CV Percent Change	Min CV Percent Change	Max CV Percent Change	Median Est. Haddock Difference (mt)	Min Stratum Observed Trips
STAT_522 ~ May-Oct/Nov-Apr	3	-4.42%	-8.72%	0.36%	-0.6	2
STAT_522 ~ May-Dec/Jan-Apr	3	-4.49%	-8.72%	0.36%	-0.6	2
STAT_522 ~ Quarterly	3	-4.48%	-8.45%	3.61%	-9.8	1
STAT_522 ~ Gear	3	-6.20%	-14.06%	5.88%	4.4	4
STAT_522 ~ Vessel Category	4	-6.01%	-24.57%	-0.21%	3.7	10
STAT_522 ~ Trip Landings Category	4	-6.65%	-19.02%	-3.66%	2.2	1
STAT_522	4	-4.98%	-11.4%	-1.2%	2.6	23

The two best performing combination stratifications were: (1) STAT_522 ~ Vessel Category, and (2) STAT_522 ~ Trip Landings Category. Despite STAT_522 ~ Trip Landings Category providing a slightly better median CV percent change, the low sample size in this stratification may be limiting. STAT_522 ~ Vessel Category offers nearly the same CV improvement but also has ten times the minimum observed trips in each stratum. Therefore STAT_522 ~ Vessel Category along with the baseline, STAT_522, and industry requested quarterly and May-Oct/Nov-Apr temporal stratifications were processed with the discaRd bootstrap model (Galuardi et al., 2016;

Linden, et al., 2016) to evaluate in-season variability and responsiveness to the different transition rates (figures 8-17).

Bootstrap model runs were completed for all fishing years (n=50) with somewhat muted differences in haddock estimation and CV performance (table 5). Results from 2015 must be interpreted carefully because no fishery was active after the area was closed on October 22, 2015. Overall, the stratifications that performed the best in terms of CV reduction during the initial analysis (tables 3 and 4) did so as well in the bootstrap model. The moving window transition rate had more meaningful impacts on the in-season estimation variability than any of the stratification options, which is reflected by a generally higher CV for the moving window transition rate compared to the baseline five trip transition rate. The five trip transition rate provided lower CVs on average across all stratification alternatives except for the baseline stratification (table 6). Stratifying by statistical area 522 and grouping all other statistical areas into other GB produced the best results. When it was applied with a five trip transition rate it produced lower CVs in four of the five fishing years, the lowest average CV (21.9%), and the best average percentage CV improvement (-8.3%) when compared to the baseline alternative (table 6). The forecasted best stratification alternative from table 4 (combination STAT_522 ~ Vessel Category stratification) performed slightly worse than the STAT_522 alternative. Given that both alternatives are very similar, the more general STAT_522 had nearly double the number of minimum stratum observed trips (n=23) compared to STAT_522 ~ Vessel Category (n=10), which likely contributed to its superior CV performance. In terms of CV, the area based stratification alternatives perform better than the temporal (seasonal) alternatives. However, the seasonal alternatives produced lower average differences in estimated haddock when calculating the difference between the median bootstrapped haddock estimate and the estimate produced by the quota monitoring method (table 5). The quarterly (May-Jul, Aug-Oct, Nov-Jan, and Feb-Apr) was the best performing temporal stratification, while the seasonal (May-Oct and Nov-Apr) alternative performed the worst out of all the alternatives.

Stratification alternatives were stronger drivers of overall estimate precision while transition rates had more influence on the variability of in-season day to day point estimates (figures 8-17). The moving window has a narrower estimation range earlier in the fishing year that gradually expands until it approaches the range of the five trip transition rate (figure 9). The moving window transition rate is characterized by punctuated swings within the year risking premature closures in 2013 and 2014, while extending the season in 2015 under most stratification alternatives. Employing the moving window appears to be a calculated risk because it tends to have a reduced risk of premature closure earlier in the fishing year, but a higher risk later in the year as evidenced by the differences in the first day of year with a greater than zero $P(>0)$ and greater than 50% $P(>0.5)$ probability of exceeding the cap (table 5). This type of behavior could be beneficial to the GB haddock catch cap which tends to consume most of the catch cap quota within the first half of the fishing year (figures 8-17). Furthermore, haddock catch rates are lower in the winter months and higher during the spring and summer (figure 4). The moving window accounts for this dynamic as seen in its mediating effect on the steepness of catch rates in May-August of 2012 and 2013 (figure 9). This influence of trend from the prior year has a counter risk if the prior year haddock catch rates were higher, evidenced by higher May-September estimates than the quota monitoring baseline method in 2014 and 2015.

Table 5. GB haddock catch cap bootstrap model output, fishing years 2011-2015

				Day Exceed Cap		Haddock Catch (mt)				
Stratification	**Transition Rate**	**Year**	**P(>Cap)**	**P(>0)**	**P(>0.5)**	**Mean**	**Median**	**SD**	**Median-QM**	**CV**
Baseline (GB Stock Area)	5 Trips	2011	0%			102	101	20	1	20%
		2012	71%	11-Sep	2-Apr	310	309	43	0	14%
		2013	62%	7-Aug	16-Apr	292	293	54	-1	18%
		2014	2%	21-Aug		113	112	22	1	20%
		2015	49%	15-Sep		262	226	156	25	60%
	Moving Window	2011	0%			101	100	20	0	20%
		2012	68%	2-Oct	2-Apr	307	307	46	-4	15%
		2013	64%	2-Oct	12-Feb	294	297	55	2	19%
		2014	2%	2-Oct	22-Jan	113	112	22	1	19%
		2015	53%	22-Sep	19-Jan	261	237	143	24	55%
May-Jul,Aug-Oct,Nov-Jan, and Feb-Apr	5 Trips	2011	0%			99	98	19	-2	19%
		2012	72%	18-Sep	2-Apr	332	330	81	22	24%
		2013	71%	14-Aug	16-Apr	304	306	55	12	18%
		2014	1%	11-Sep		110	109	19	-2	17%
		2015	42%	15-Sep		220	210	92	-17	42%
	Moving Window	2011	0%			99	98	20	-2	21%
		2012	70%	2-Oct	2-Apr	329	327	76	18	23%
		2013	73%	2-Oct	19-Feb	307	306	55	14	18%
		2014	2%	22-Jan	19-Mar	108	106	22	-4	20%
		2015	32%	22-Sep		200	186	94	-38	47%
May-Oct and Nov-Apr	5 Trips	2011	0%			103	102	21	2	20%
		2012	74%	18-Sep	2-Apr	333	330	73	23	22%
		2013	61%	7-Aug	16-Apr	292	289	55	-1	19%
		2014	2%	11-Sep		113	113	22	1	20%
		2015	50%	15-Sep	20-Oct	258	228	148	20	57%
	Moving Window	2011	0%			102	102	20	2	20%
		2012	75%	25-Sep	2-Apr	337	337	71	26	21%
		2013	62%	9-Oct	12-Feb	292	293	56	0	19%
		2014	1%	15-Jan	5-Feb	98	94	24	-15	24%
		2015	50%	22-Sep		267	227	155	29	58%
Stat 522 and Other GB	5 Trips	2011	0%			102	101	20	1	19%
		2012	69%	18-Sep	2-Apr	309	309	44	-1	14%
		2013	71%	7-Aug	16-Apr	305	303	55	12	18%
		2014	2%	22-Jan		116	116	21	4	18%
		2015	77%	15-Sep	29-Sep	320	305	127	82	40%
	Moving Window	2011	0%			102	101	19	1	19%
		2012	68%	18-Sep	2-Apr	307	306	44	-3	14%
		2013	71%	25-Sep	12-Feb	307	307	57	14	19%
		2014	3%	11-Sep	25-Sep	117	116	22	5	19%
		2015	78%	29-Sep	19-Jan	334	317	155	96	46%
Stat 522 and Other GB and 0-120ft and 120ft+	5 Trips	2011	0%			106	106	20	5	19%
		2012	64%	11-Sep	2-Apr	303	301	43	-8	14%
		2013	72%	7-Aug	16-Apr	306	306	56	14	18%
		2014	4%	25-Sep		117	116	23	5	20%
		2015	74%	15-Sep	29-Sep	310	292	133	73	43%
	Moving Window	2011	0%			105	104	20	4	19%
		2012	71%	2-Oct	2-Apr	308	307	43	-3	14%
		2013	73%	25-Sep	5-Feb	308	307	57	15	19%
		2014	3%	18-Sep	22-Jan	115	114	22	3	19%
		2015	90%	22-Sep	29-Sep	442	402	224	205	51%

Table 6. Summary statistics: 2011-2015 GB haddock catch cap bootstrap model output

			CV		CV Percent Change		QM-Median (mt)	
Stratification	Transition Rate	# Years CV Improve	Mean	Median	Mean	Median	Mean	Median
Baseline (GB Stock Area)	5 Trips	0	26.2%	19.5%	0.0%	0.0%	5	1
	Moving Window	2	25.6%	19.3%	0.7%	1.9%	5	1
May-Jul,Aug-Oct,Nov-Jan, and Feb-Apr	5 Trips	4	24.1%	19.1%	6.2%	-2.7%	3	-2
	Moving Window	2	25.8%	20.6%	10.5%	3.6%	-2	-2
May-Oct and Nov-Apr	5 Trips	1	27.6%	20.2%	12.2%	3.0%	9	2
	Moving Window	1	28.5%	21.2%	15.9%	3.7%	8	2
Stat 522 and Other GB	5 Trips	4	21.9%	18.4%	-8.3%	-2.4%	20	4
	Moving Window	3	23.5%	19.0%	-4.6%	-2.2%	23	5
Stat 522 and Other GB and 0-120ft and 120ft+	5 Trips	3	22.8%	18.9%	-5.4%	-0.3%	18	5
	Moving Window	3	24.4%	19.2%	-3.2%	-0.9%	45	4

Stratification Analysis: River Herring and Shad Catch Caps

Due to limited sample size and narrow baseline stratification definitions, only RHS SNE bottom trawl was evaluated for alternative stratifications. Initial stratifications from five broad stratification categories were selected and evaluated (table 7). Temporal stratifications were selected according to several factors. The May-October stratification was based on seasonal fleet activity which tends to be confined to this period. The January-June stratification is a logical break for splitting the fishing year into two halves. The gear stratification was the lowest resolution available within the fisheries dependent data sources used for monitoring. Two area stratifications were selected: (1) statistical area, and (2) statistical area 539 and all other SNE. Statistical area 539 contains the majority of effort in SNE and is a reasonable grouping. Vessel category and trip landings stratifications were selected by visually inspecting and identifying natural breaks in trip distributions.

Table 7. RHS SNE bottom trawl initial stratifications

Stratification Category	Stratification Options
Temporal	May-October/November-April January-June/July-December
Gear	Bottom gear types
Area	Statistical Reporting Area STAT_539/OTHER_SNE
Vessel Category	Less than 90 ft/90 ft and greater
Trip Landings Category	Less than 125,000 lbs/125,000 lbs and greater

Observed trips from fishing years 2014-2015 were pooled together and stratified by the options described in table 7. Bootstrapped ratio estimator distributions were constructed for each stratum and compared to the overall fishing year 2014-2015 ratio estimator distribution. None of the seven stratifications evaluated yielded meaningful Z-values and all stratified distributions were very similar to the baseline distribution. CV analysis of individual years did not provide improved information (table 8). Many of the stratifications had limited sample size, and several could not be analyzed (Trip Landings Category, Area, and Gear) due to the lack of observed trips. These constraints precluded any secondary CV analysis of combinations of these initial stratifications.

Table 8. Initial herring RHS SNE bottom trawl catch cap stratification CV and RHS estimation performance compared to baseline, fishing years 2014-2015

Stratification	# Years CV Improve	Median CV Percent Change	Min CV Percent Change	Max CV Percent Change	Median Est. RHS Difference (mt)	Minimum Stratum Observed Trips
May-Oct/Nov-Apr	0	0.00%	0.00%	0.00%	0.0	20
Jan-Jun/Jul-Dec	2	-7.55%	-11.62%	-3.48%	-2.6	7
Stat 539/Other SNE	1	2.19%	-24.60%	28.98%	3.0	5
Vessel Category	2	-22.64%	-42.56%	-2.72%	9.9	1

Only 2015 data were processed with the bootstrap model (n=12) to evaluate in-season variability and responsiveness to the different transition rates because 2015 was the only complete year of RHS herring catch cap implementation. The Vessel category and May-Jun/Jul-Dec stratifications in the RHS SNE bottom trawl catch cap suggested potential CV gains and were processed along with remaining RHS herring catch cap base line stratifications (figures 18-23). The single complete year available for analysis along with small sample size makes the performance of alternative stratifications unclear. Results are not definitive and informational only.

Table 9. 2015 herring RHS catch cap bootstrap model summary output

				Day Exceed Cap		RHS Catch (mt)				
Stratificatio	**Transition Rate**	**Catch Cap**	**P(>Cap)**	**P(>0)**	**P(>0.5)**	**Mean**	**Median**	**SD**	**Median-QM**	**CV**
Baseline (RHS Herring Catch Caps)	5 Trips	CC MW	0%			1	1	1	0	72%
		GOM MW	0%			11	11	9	0	80%
		SNE BT	66%	14-Feb	31-Dec	100	100	24	-1	24%
		SNE MW	0%			61	65	11	-4	17%
	Moving Window	CC MW	0%			1	1	1	0	69%
		GOM MW	0%			13	13	11	2	82%
		SNE BT	67%	19-Dec	31-Dec	100	100	24	0	24%
		SNE MW	0%			76	81	13	11	18%
Jan-Jun and Jul-Dec	5 Trips	SNE BT	67%	14-Feb	31-Dec	100	98	23	-1	23%
	Moving Window	SNE BT	69%	21-Feb	31-Dec	101	100	24	1	24%
Less than 90 ft and greater than 90 ft	5 Trips	SNE BT	45%	21-Mar		87	86	21	-13	24%
	Moving Window	SNE_BT	69%	19-Dec	26-Dec	104	110	30	4	28%

Bootstrap model results are described in table 9. They showed small, but broad based CV declines across catch caps compared to the baseline 2015 CV (table 1) as calculated by equation 5 (Palmer, 2010). However, this is likely not meaningful and a product of different methods in CV calculation and small sample sizes. The CV in table 9 is derived from the bootstrapped distribution of incidental catch estimates, whereas table 1 is analytically calculated (Cochran, 1977). When the alternative RHS SNE bottom trawl stratifications are compared to its baseline (five trip transition rate), there is essentially no difference in CVs.

Results: Atlantic Mackerel Fishery

The RHS mackerel catch cap was effective for complete years in 2014 and 2015. Despite this additional year, the RHS mackerel catch cap still suffers from the same small sample size limiting analysis of the RHS herring catch caps. This is largely due to low effort in the mackerel fishery in the last several years. The impact is buffered to a certain degree by the more general RHS mackerel catch cap baseline stratification definition, which is not constrained by area or gear, just a 20,000 lb mackerel landing threshold. This allows for more flexible stratifications.

Observer coverage changed dramatically from 2014 to 2015 with coverage rates declining from 38% to 7% (table 10). Only four trips were observed in 2015, which is not enough to get the RHS incidental catch rate out of the transition phase to 100% in-season weighting according to the current quota monitoring methodology five trip transition rate (equation 3).

Table 10. Atlantic mackerel fishery realized RHS catch cap CV and observer coverage (in parentheses), 2014-2015

	Fishing Year[1]: CV (Observer Coverage)	
Catch Cap	**2014**	**2015**
RHS-Mackerel	48.9% *(37.8%)*	22.7% *(7.3%)*

Source: GARFO Quota Monitoring Database as of 5/22/2016

[1]Catch cap fishing year: river herring/shad = calendar year

The baseline 2014-2015 CV and observer coverage rates for the RHS mackerel catch cap are detailed in table 10. The relationship between observer coverage and the CV is described in figure 6, the actual CV and observer coverage for each year is indicated with a black dot. The CV is variable between 2014 and 2015, requiring observer coverage ranging between 4% and 62% to achieve a CV of 30%.

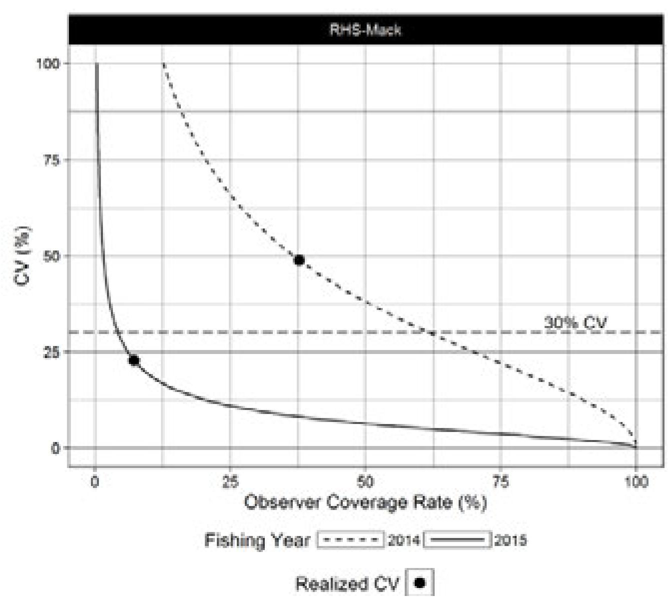

Figure 6. 2014-2015 relationship between observer coverage and estimated CV for each the RHS mackerel catch cap with actual CV and observer coverage for each catch cap year (black dot)

Stratifications Analysis: River Herring and Shad Catch Cap

Sample size is quite limiting in the RHS mackerel catch cap and only a coarse stratification analysis was possible for broad informational purposes about potential stratifications in this catch cap. Initial stratifications from five broad stratification categories were selected and evaluated (table 11). Temporal stratifications were selected according to several factors. The May-October stratification was based on seasonal fleet activity which tends to be confined to this period. The January-June stratification was a logical break for splitting the fishing year into two halves. The gear stratification was defined according to the two dominant gear types: (1) bottom trawl and (2) midwater trawl. A single area stratification of STAT_522 and OTHER_AREAS was selected despite multiple areas covered by the catch cap because the majority of available data was from statistical area 522. Vessel category and trip landings stratifications were selected by visually inspecting and identifying natural breaks in trip distributions. This process was aided by iterating through all potential splits within these classes and identifying the split that yielded the minimum CV.

Table 11. RHS mackerel catch cap initial stratifications

Stratification Category	Stratification Options
Temporal	May-October/November-April January-June/July-December
Gear Category	Bottom and Midwater Trawl
Area	STAT_522/OTHER_AREAS
Vessel Category	Less than 120 ft/120 ft and greater
Trip Landings	Less than 700,000 lbs/700,000 lbs and greater

Observed trips from fishing years 2014-2015 were pooled together and stratified by the options described in table 11. Bootstrapped ratio estimator distributions (grey histogram) were constructed for each stratification and compared to the overall fishing year 2014-2014 RHS ratio estimator distribution (dashed line density plot) (figures 7). The STAT_522 stratification was the only stratification with an acceptable minimum sample size (>10) that yielded an absolute Z-value greater than two, indicating a substantial divergence between the baseline RHS ratio estimator and the stratified ratio estimator. Vessel category, gear category, and the Jan-Jun/Jul-Dec stratifications had diverging distributions, but their sample sizes were too small (<10). The remaining stratifications had minimal differences.

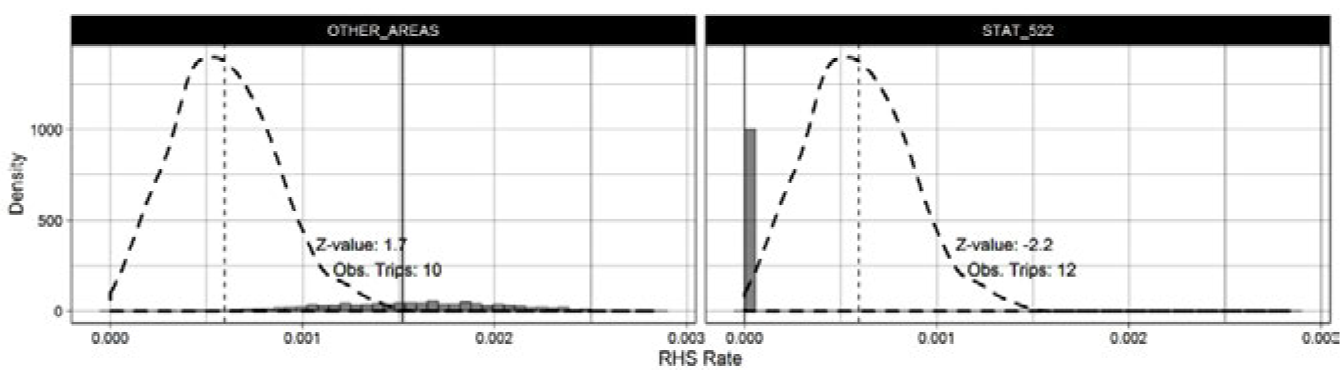

Figure 7. 2014-2015 RHS mackerel catch cap statistical area 522 stratified ratio estimator compared to baseline ratio estimator. Stratified ratio estimator and bootstrapped distribution represented by solid black vertical line and grey histogram. Baseline ratio estimator and bootstrapped distribution represented by dashed vertical line and density plot.

The results of the individual annual CV analysis of each strata (table 12) conflict somewhat with the ratio estimator bootstrap analysis (figure 7). Several of the stratifications that appeared to not have substantially different ratio estimators exhibit considerable CV gains, while the STAT_522 stratification performs relatively poorly with regard to CV performance. This is likely attributable to the low available sample size and underscores the need to interpret these results with caution.

Table 12. Initial RHS mackerel catch cap stratification CV and RHS estimation performance compared to baseline, fishing years 2014-2015

Stratification	# Years CV Improve	Median CV Percent Change	Min CV Percent Change	Max CV Percent Change	Median Est. RHS Difference (mt)	Minimum Stratum Observed Trips
May-Oct/Nov-Apr	1	0.78%	-0.15%	1.71%	NA	0
May-Jun/Jul-Dec	2	-61.59%	-81.06%	-42.12%	1.8	1
Gear Category	2	-42.95%	-82.89%	-3.01%	NA	0
STAT_522/OTHER_AREAS	2	-8.34%	-16.29%	-0.39%	NA	0
Vessel Category	1	-25.38%	-52.54%	1.78%	0.3	2
Trip Landings	1	2.82%	-0.15%	5.79%	NA	0

*NA: indicates stratifications where RHS could not be estimated because no observed trips existed, but fleet landings were reported from within the stratification

Despite the general uncertainty, the May-Jun/Jul-Dec and vessel category stratifications were processed with the discaRd bootstrap model along with the baseline stratification (n=12) to evaluate in-season variability and responsiveness to different transition rates (figures 24-29). Bootstrap model results are described in table 13. They show similar results to those seen from the herring RHS bootstrap model output where the bootstrapped CVs are slightly lower than the calculated CV (table 10). Again, this is likely not meaningful and a product of different methods in CV calculation and small sample sizes. The temporal, half year (Jan-Jun and Jul-Dec) stratification returned substantial CV declines (33%-59%) compared to the baseline with both transition rates. However this needs to be interpreted with caution because this stratification has a minimum stratum observed trip count of one (table 12).

Table 13. 2014-2015 mackerel RHS catch cap bootstrap model summary output

				Day Exceed Cap		RHS Catch (mt)				
Stratification	Transition	Year	P(>Cap)	P(>0)	P(>0.5)	Mean	Median	SD	Median-QM	CV
Baseline (RHS Mackerel Catch Cap)	5 Trips	2014	0			5	5	3	0	51%
		2015	0			12	13	3	0	22%
	Moving Window	2014	0			5	5	3	0	51%
		2015	0			14	14	3	1	24%
Jan-Jun and Jul-Dec	5 Trips	2014	0			7	7	2	2	34%
		2015	0			11	11	2	-2	14%
	Moving Window	2014	0			9	9	3	3	31%
		2015	0			13	13	1	0	9%
Less than 120 ft and greater than 120 ft	5 Trips	2014	0			6	5	3	0	49%
		2015	0			9	10	2	-3	20%
	Moving Window	2014	0			5	5	3	0	50%
		2015	0			13	13	2	1	18%

Discussion

Stratification alternatives in the GB haddock and RHS catch caps provided marginal improvements to incidental catch estimate precision. Low sample size and/or effort in the RHS catch caps prohibited meaningful conclusions about the effect of alternative stratifications. The best performing and most viable stratification alternative for increasing precision in the GB haddock catch cap was the STAT_522 alternative that separated the cap into two strata: (1) statistical area 522, and (2) all other GB. No viable stratification alternatives could be identified in the Atlantic mackerel and herring RHS catch caps that definitively increased estimate precision. However, alternative stratification analysis for the RHS catch caps should be revisited in the future after more historical data become available. The baseline five trip transition rate consistently produced lower CVs than the moving window transition rate for the same stratification in the majority of bootstrap model runs. It is not recommended that the transition rate be changed to the moving window, however there may be support to employ the moving window transition rate for certain catch caps based on their seasonal catch dynamics.

The management definitions of the catch caps in the Atlantic herring and mackerel fisheries constrain stratification flexibility. Coupled with low sampling intensity, in certain scenarios the efficacy of alternative stratifications is limited at best or infeasible. These fisheries may be better served by a robust transition rate that is independent of stratification. An effective, accurate, and broadly applicable transition rate could be just as, if not more effective than alternate stratification schemes that are susceptible to changes in effort and sampling coverage. This is a critical consideration given that monitoring of these catch caps is required and occurs independently of these two strong drivers of estimate precision that ultimately dictate the degree of stratification options.

This analysis explored multiple transition rate options with mixed success. The moving window option was selected because of its ability access a larger volume of data and account for seasonality by using prior year observed trips to backfill data gaps for unknown periods of the year. The moving window option was also attractive because it is fully constructed from in-season trips at the end of the window period regardless of the number of trips observed. This eliminates problematic scenarios where certain strata never get out of the transition period due to low sample size under the baseline transition rate (equation 3). The tradeoff of this approach is that these low sample size events could introduce more volatility into the estimate. Other drawbacks include sensitivity to inter-annual catch trends, and the "artifact" effect from previous year catch rates on in-season estimates. This effect can be compounded if it occurs coincident to high in-season catch events that are not completely offset by the moving window. For example, if high catch events are seasonal and cluster during certain periods of the year (i.e. weeks), these events will likely not occur on the exact same day as the year prior and hence will not offset one another and they will both remain in the moving window. Therefore as the moving window enters these high catch rate periods there is a risk it will be constructed from both in-season and prior year high catch events, compounding the influence of the high catch rate period. This would explain the Feb-Mar spike in moving window catch estimates in the GB haddock catch cap in 2013-2014 (figure 9). Furthermore, this effect could be amplified when applying finer resolution stratifications because there is potential to confine the high catch rate events within a single stratum, which may explain the extreme spike in 2014 haddock estimation for the May-Oct and Nov-Dec stratification (figure 11). This type of outcome would likely be discrete, but would still increase the risk of prematurely closing a catch cap.

In addition to the moving window transition rate, a CV based transition rate was explored that operated analogously to the five trip transition rate (Hermsen, 2016). Instead of using a five trip transition period, the CV based transition rate would define the number of trips within a transition period according to the number of trips required to achieve a CV of 30% in the prior year. Preliminary simulations were run with this CV based transition rate, but the results contrasted very little with the five trip transition rate. The 0.7 weighting factor in the numerator of the transition rate (equation 3) imposes an exponential decline in the weighting of the assumed rate yielding minimal influence beyond five trips (NOAA 2010). If the CV based transition rate is revisited in the future, work should focus on identifying the optimal weighting factor to replace the existing 0.7 that would flatten the transition curve and allowing it to more effectively accommodate a larger number of trips.

The discaRd R package produced for this discard review is an invaluable toolkit that should be expanded upon in the future to enhance these types of analyses. There are immediate opportunities to leverage and scaffold existing functions in the package to improve initial stratification identification and data dimensionality reduction with CV minimization techniques.

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Appendix

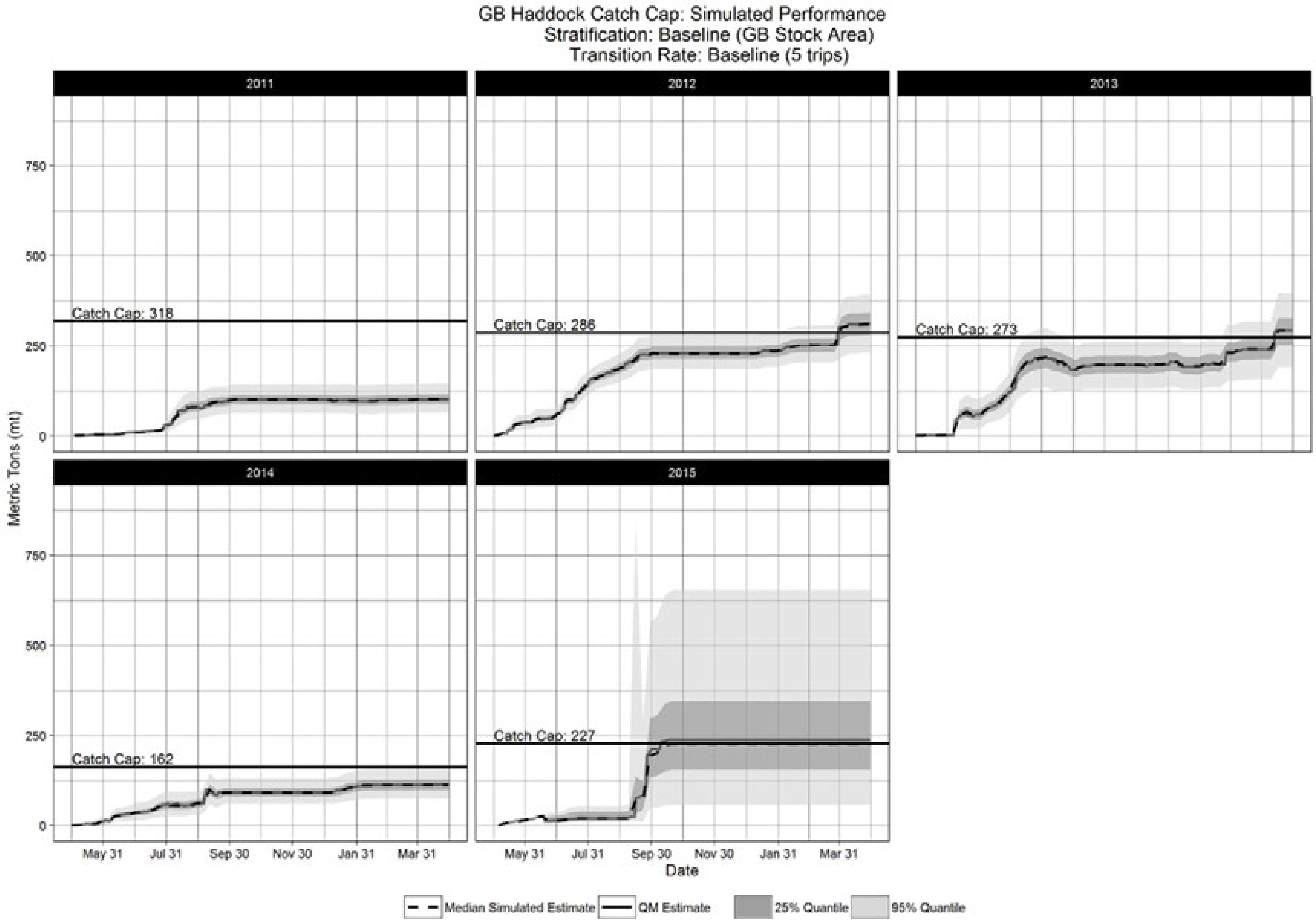

Figure 8. GB haddock catch cap simulated baseline (GB stock area) with five trip transition rate, fishing years 2011-2015*

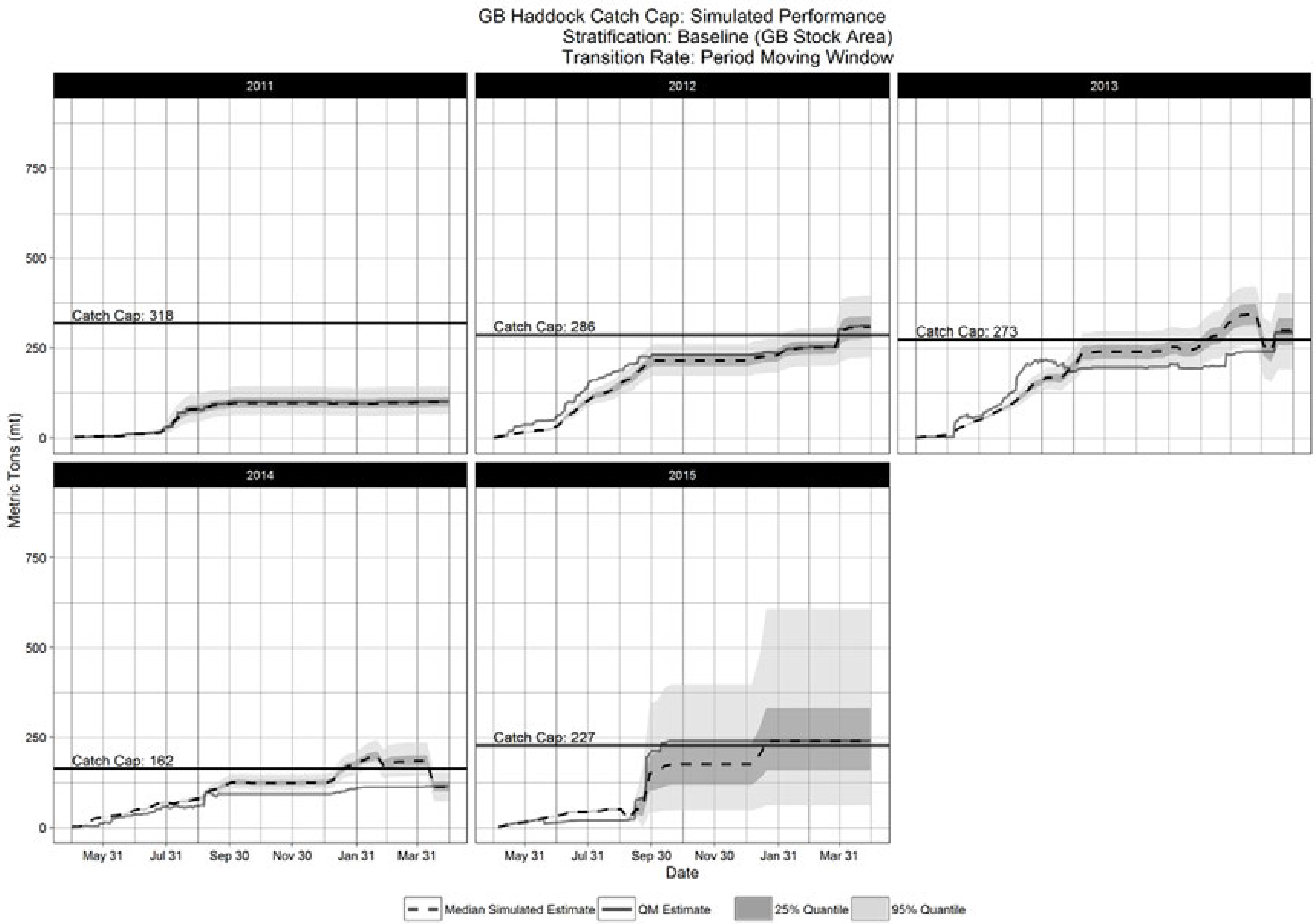

Figure 9. GB haddock catch cap simulated baseline (GB stock area) with moving window transition rate, fishing years 2011-2015*

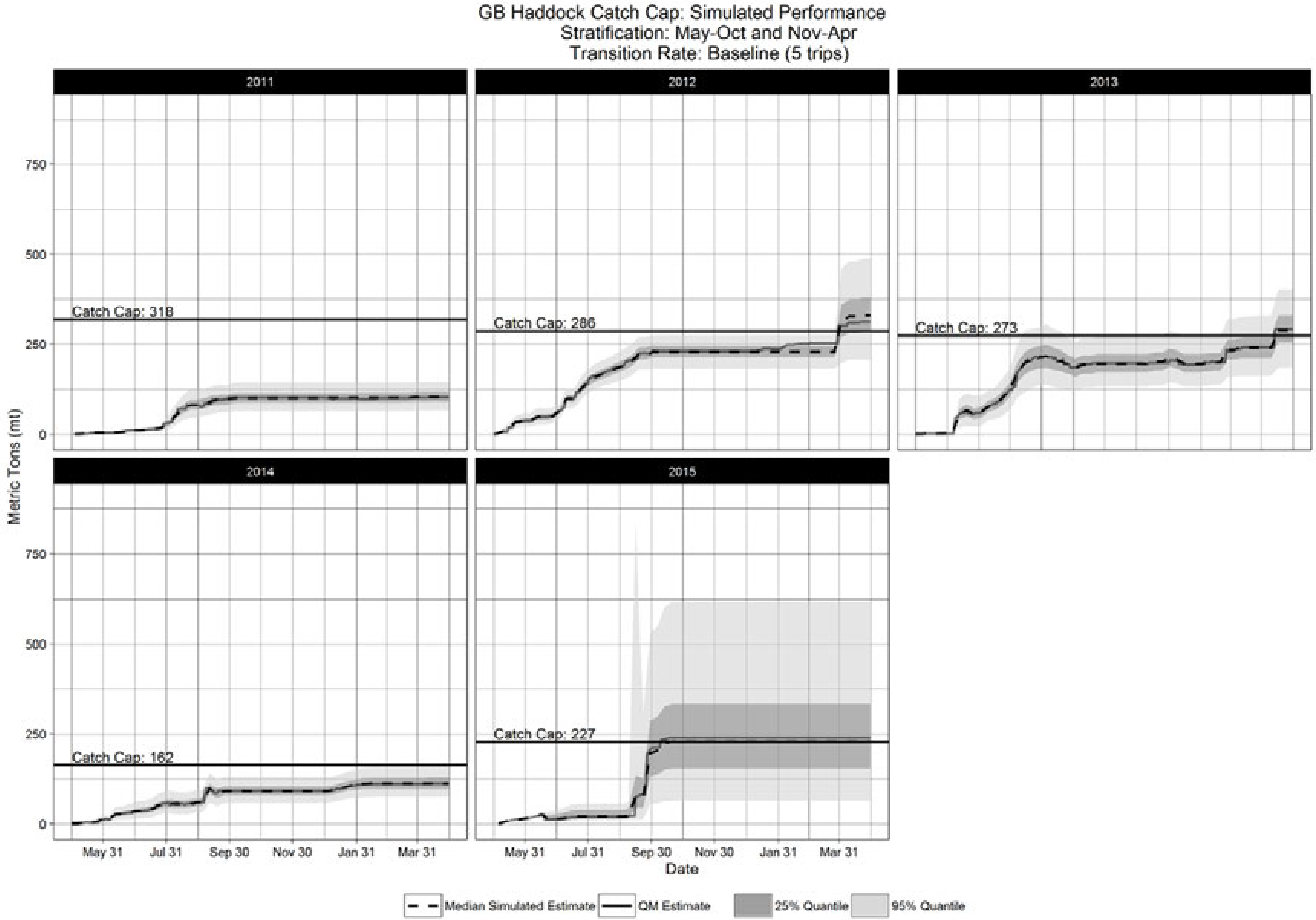

Figure 10. GB haddock catch cap simulated May-October and November-April stratification alternative with five trip transition rate, fishing years 2011-2015*

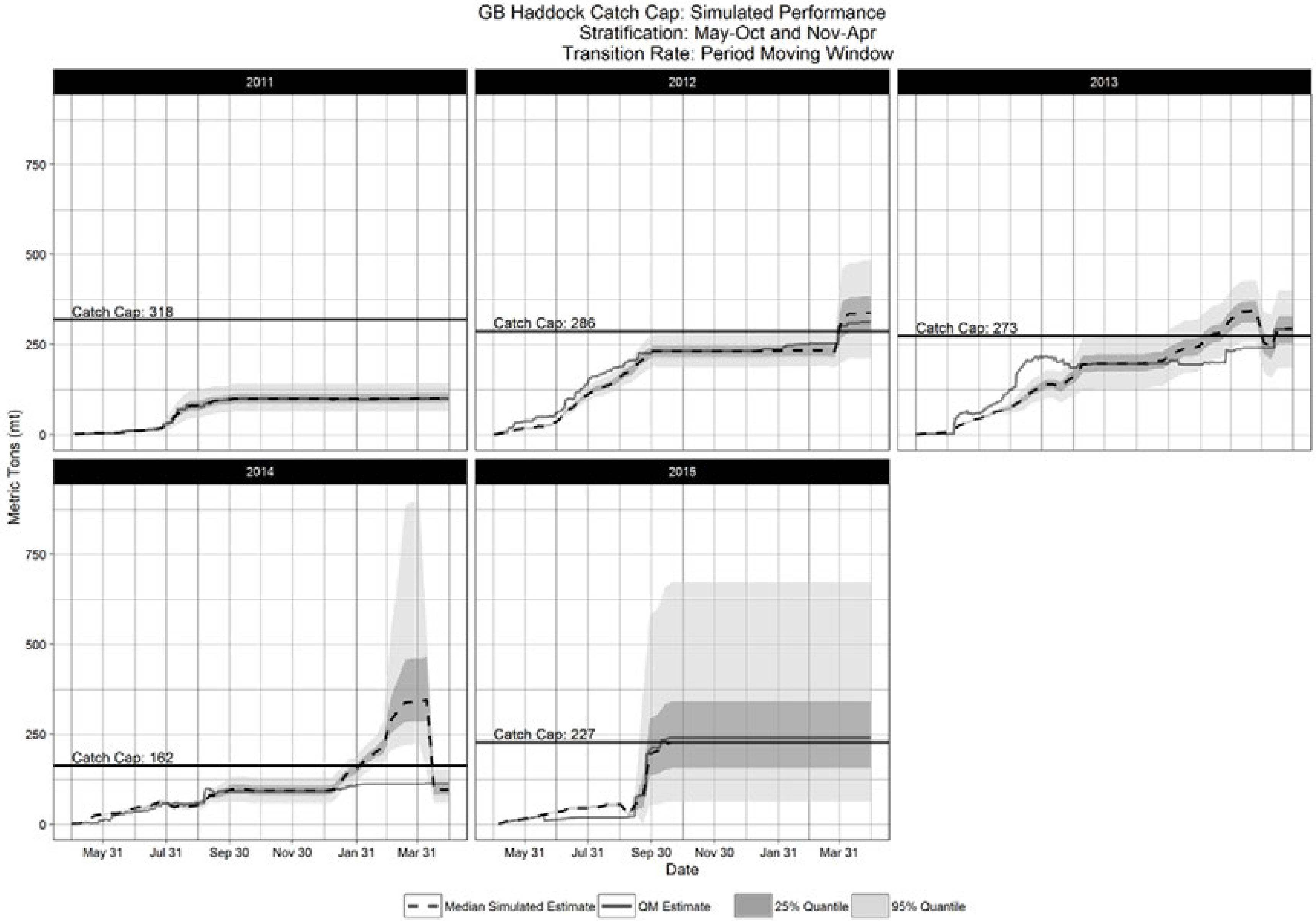

Figure 11. GB haddock catch cap simulated May-October and November-April stratification alternative with moving window transition rate, fishing years 2011-2015*

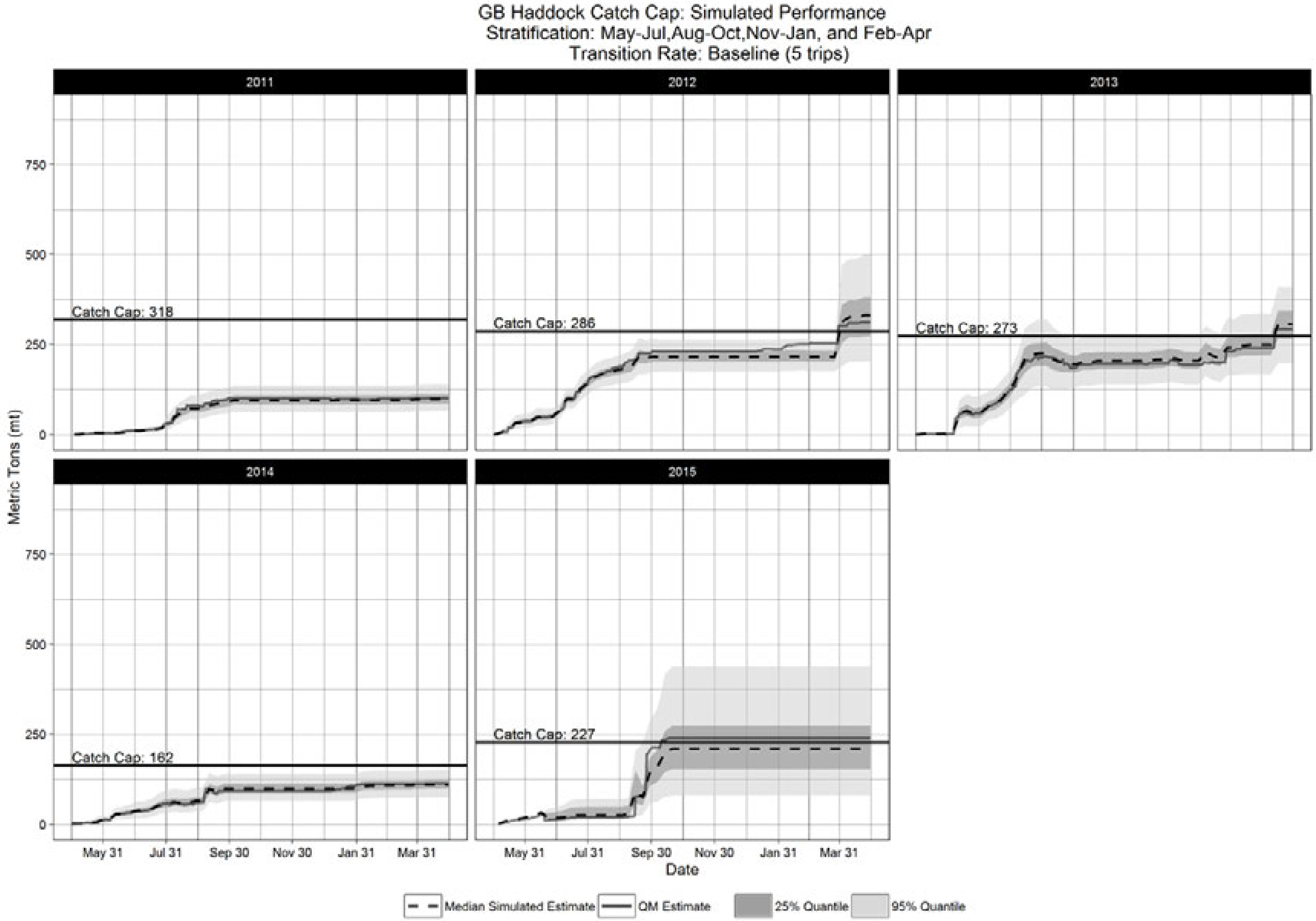

Figure 12. GB haddock catch cap simulated quarterly (May-Jul, Aug-Oct, Nov-Jan, and Feb-Apr) stratification alternative with five trip transition rate, fishing years 2011-2015*

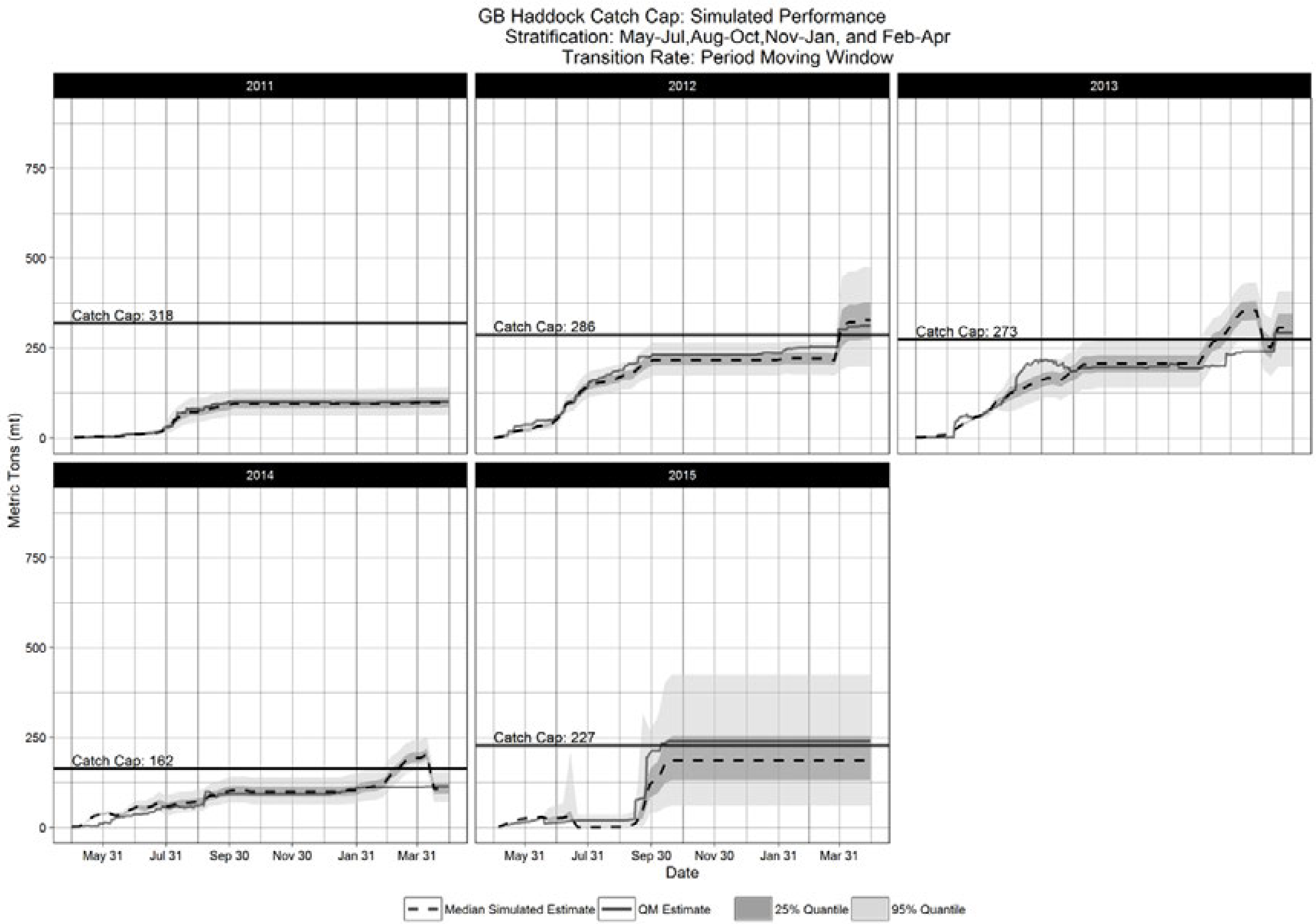

Figure 13. GB haddock catch cap simulated quarterly (May-Jul, Aug-Oct, Nov-Jan, and Feb-Apr) stratification alternative with moving window transition rate, fishing years 2011-2015*

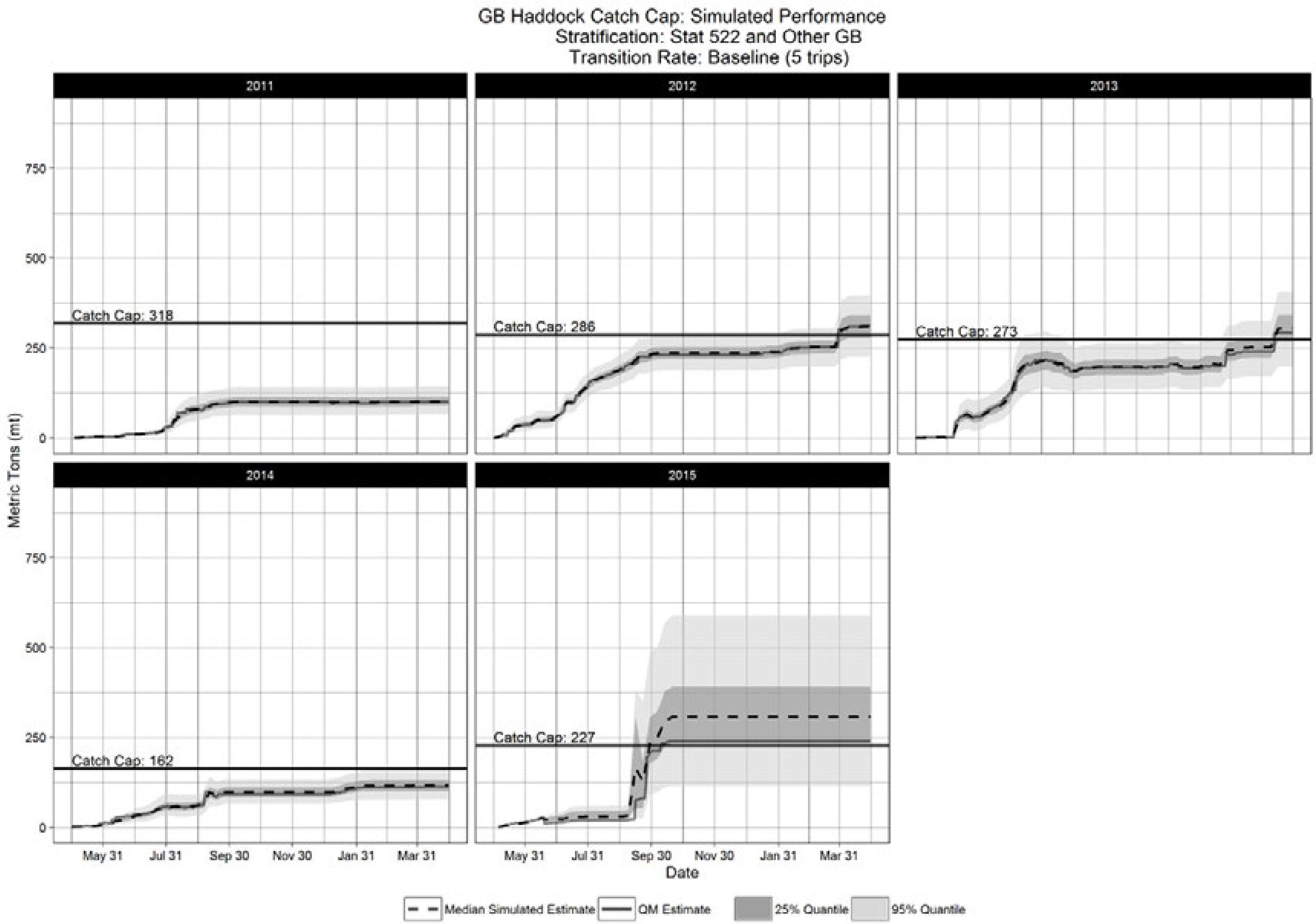

Figure 14. GB haddock catch cap simulated Statistical Area 522 and all other GB stratification alternative with five trip transition rate, fishing years 2011-2015*

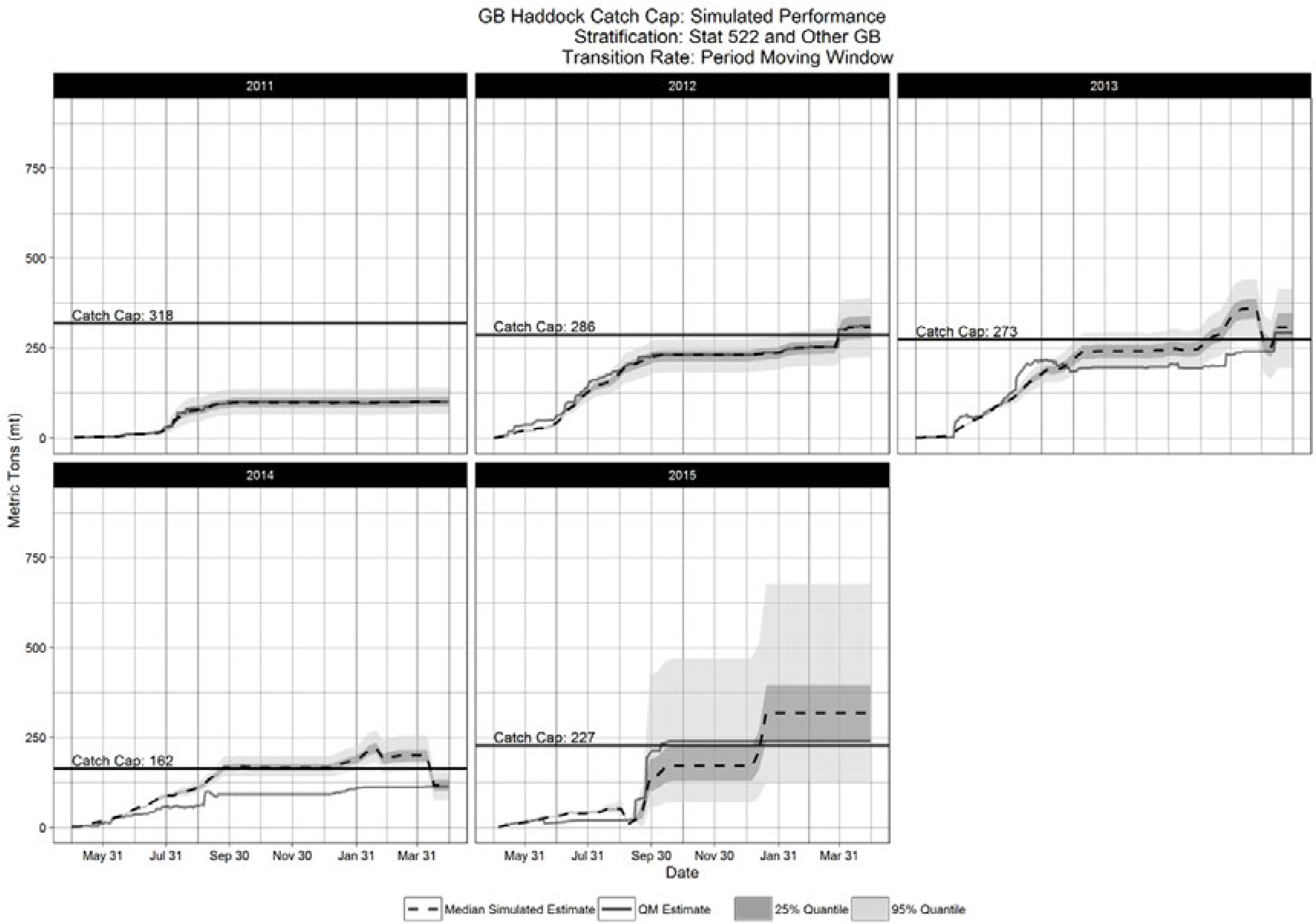

Figure 15. GB haddock catch cap simulated Statistical Area 522 and all other GB stratification alternative with moving window transition rate, fishing years 2011-2015*

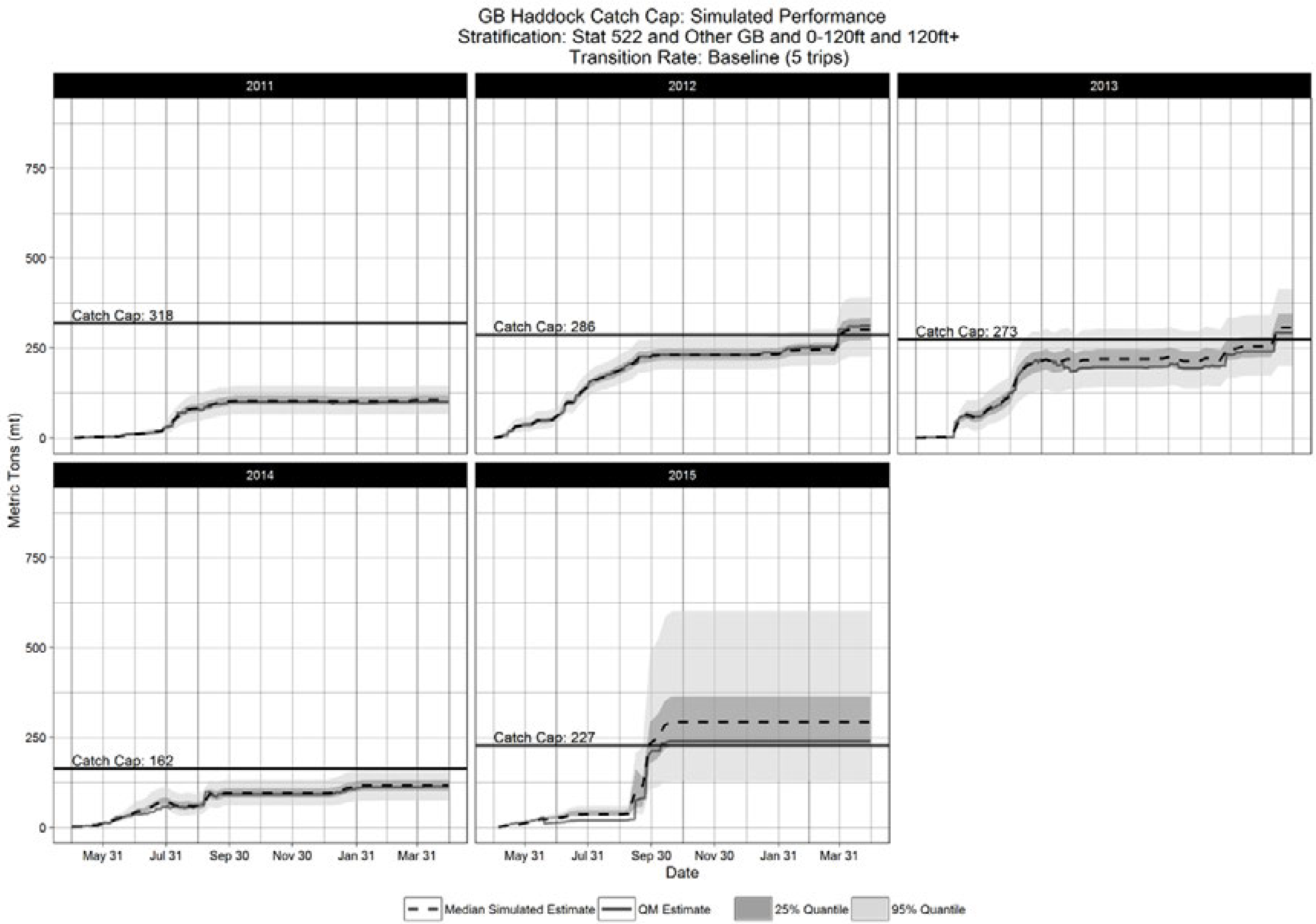

Figure 16. GB haddock catch cap simulated Statistical Area 522 and all other GB combined with vessel length category less than 120' and greater than or equal to 120'stratification alternative with five trip transition rate, fishing years 2011-2015*

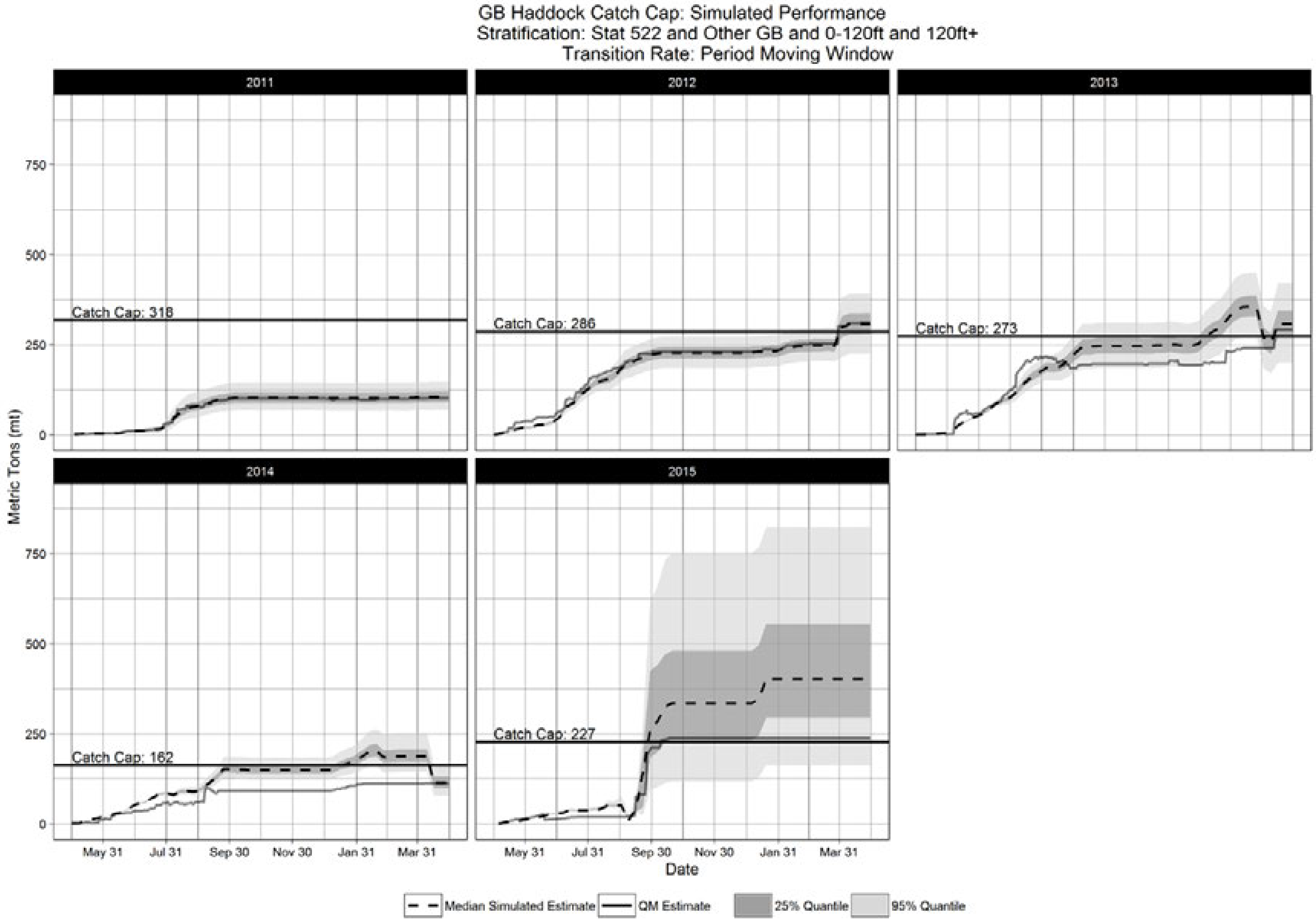

Figure 17. GB haddock catch cap simulated Statistical Area 522 and all other GB combined with vessel length category less than 120’ and greater than or equal to 120’ stratification alternative with moving window transition rate, fishing years 2011-2015*

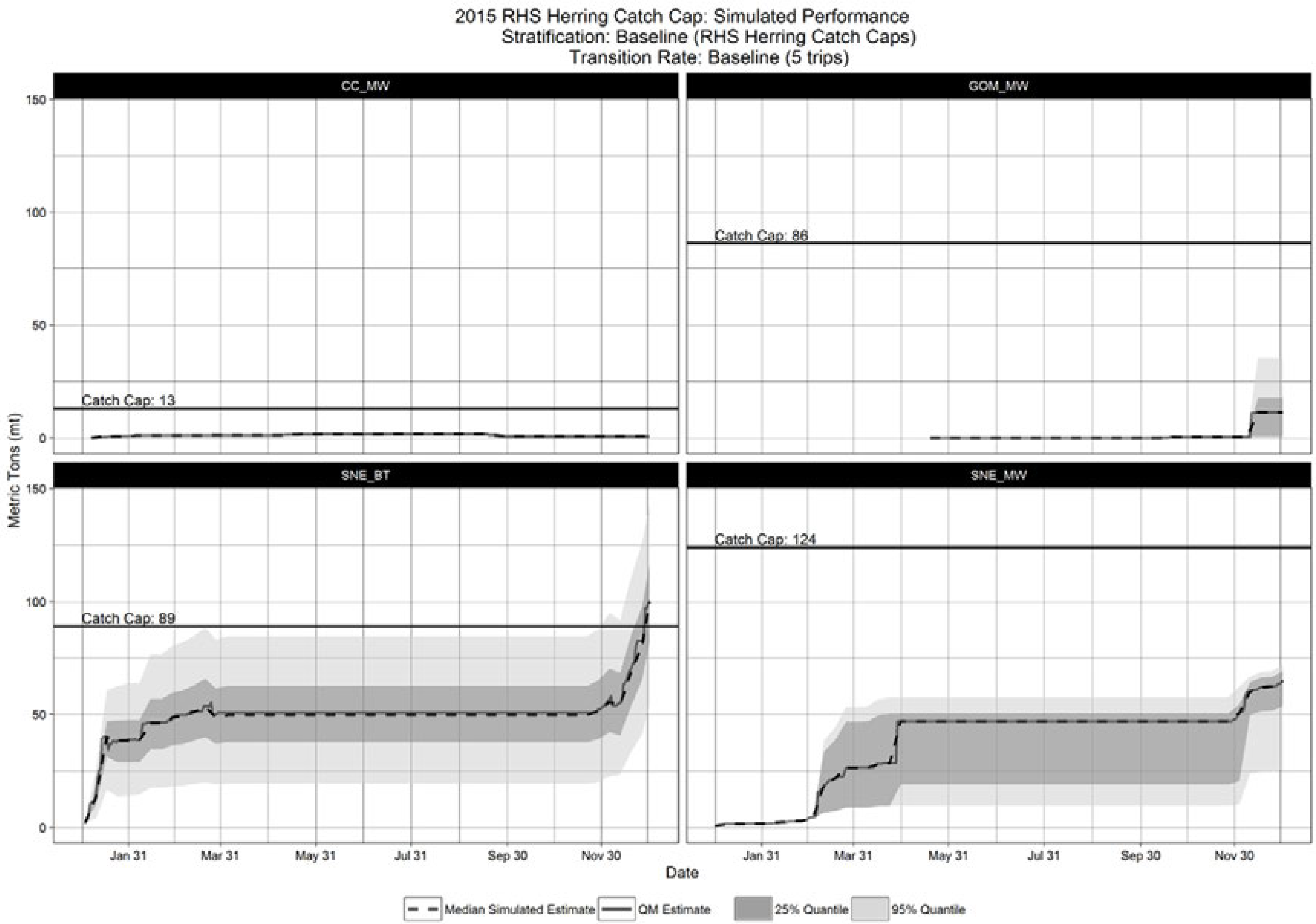

Figure 18. 2015 RHS herring catch cap simulated baseline (RHS catch cap areas and gears) stratification alternative with five trip transition rate

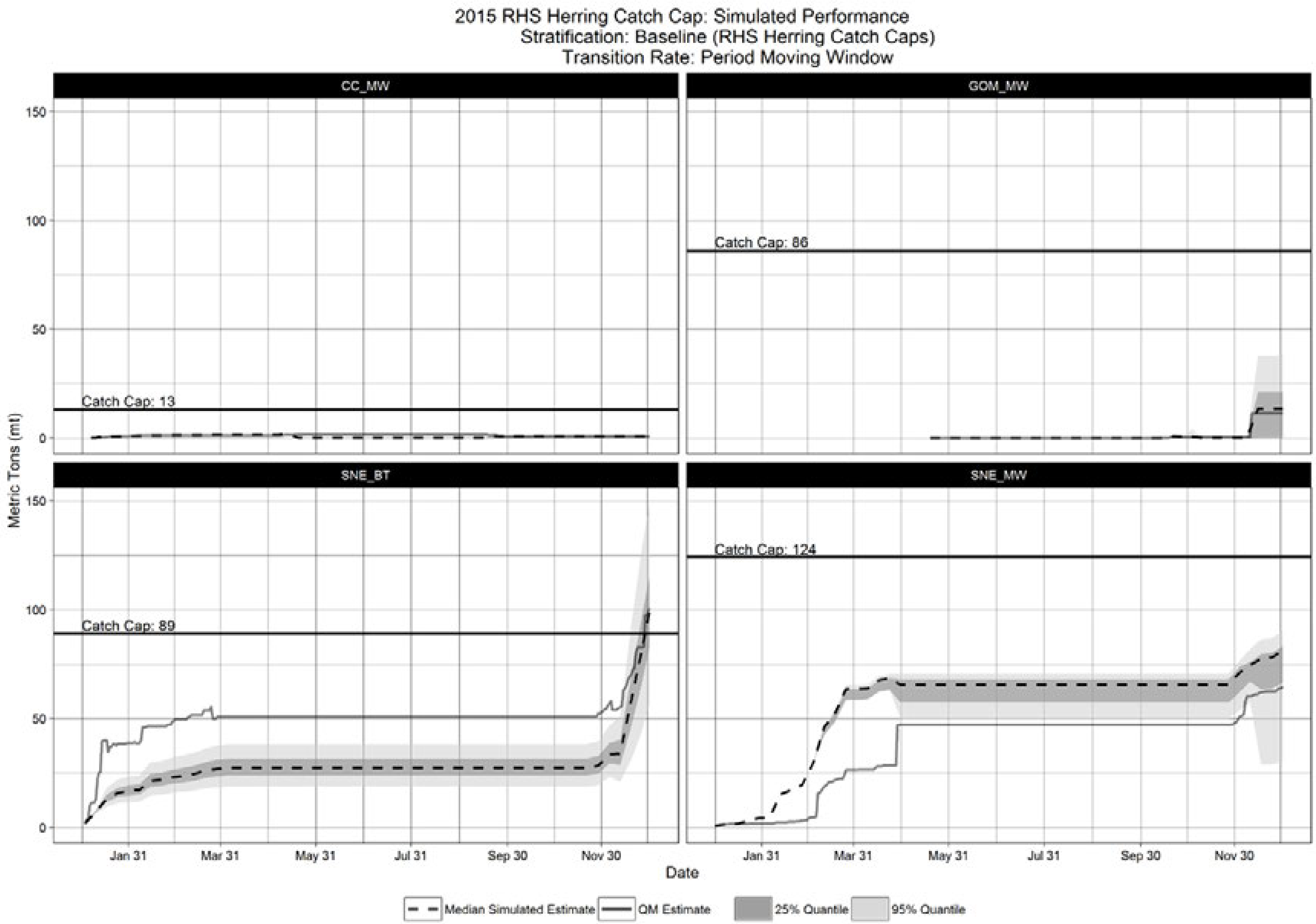

Figure 19. 2015 RHS herring catch cap simulated baseline (RHS catch cap areas and gears) stratification alternative with moving window transition rate

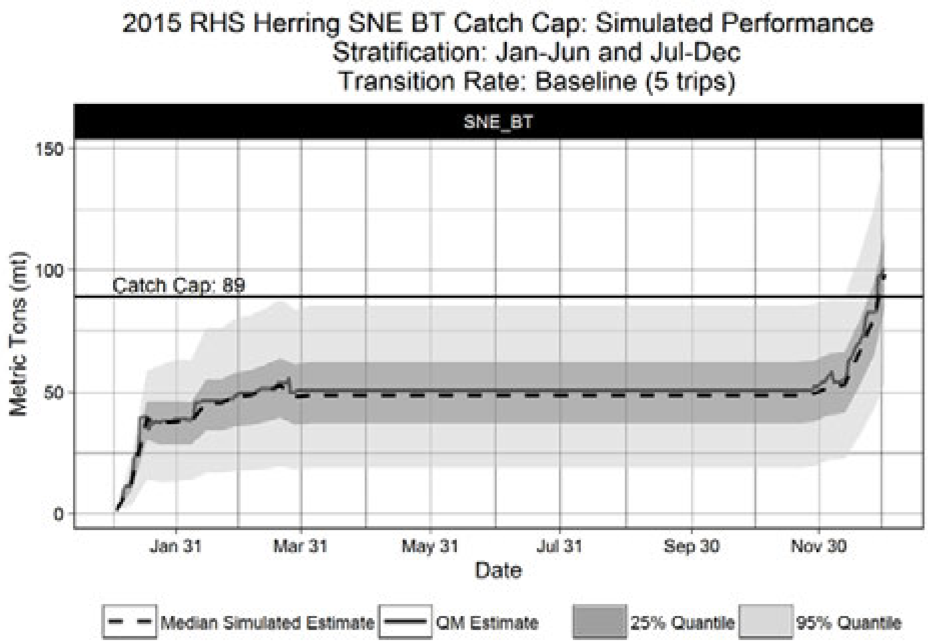

Figure 20. 2015 RHS herring SNE bottom trawl catch cap simulated half year (Jan-Jun and Jul-Dec) stratification alternative with five trip transition rate

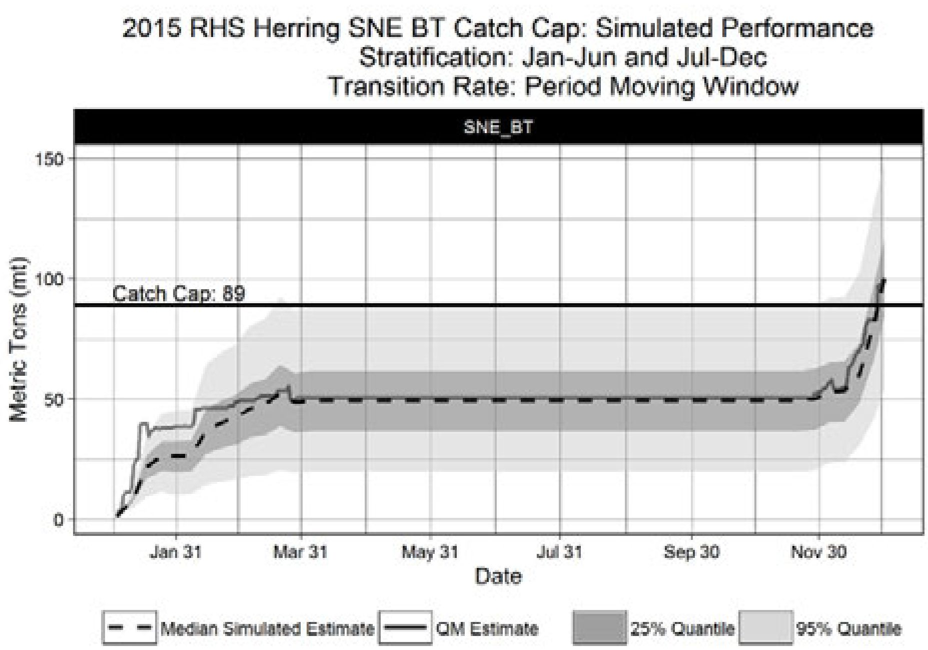

Figure 21. 2015 RHS herring SNE bottom trawl catch cap simulated half year (Jan-Jun and Jul-Dec) stratification alternative with moving window transition rate

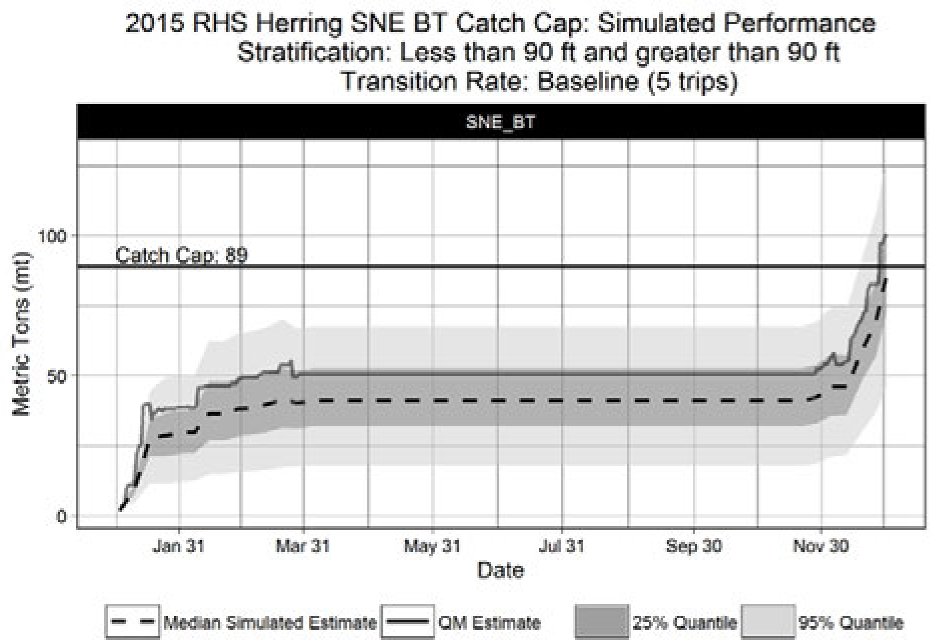

Figure 22. 2015 RHS herring SNE bottom trawl catch cap simulated vessel length category less than 90' and greater than or equal to 90' stratification alternative with five trip transition rate

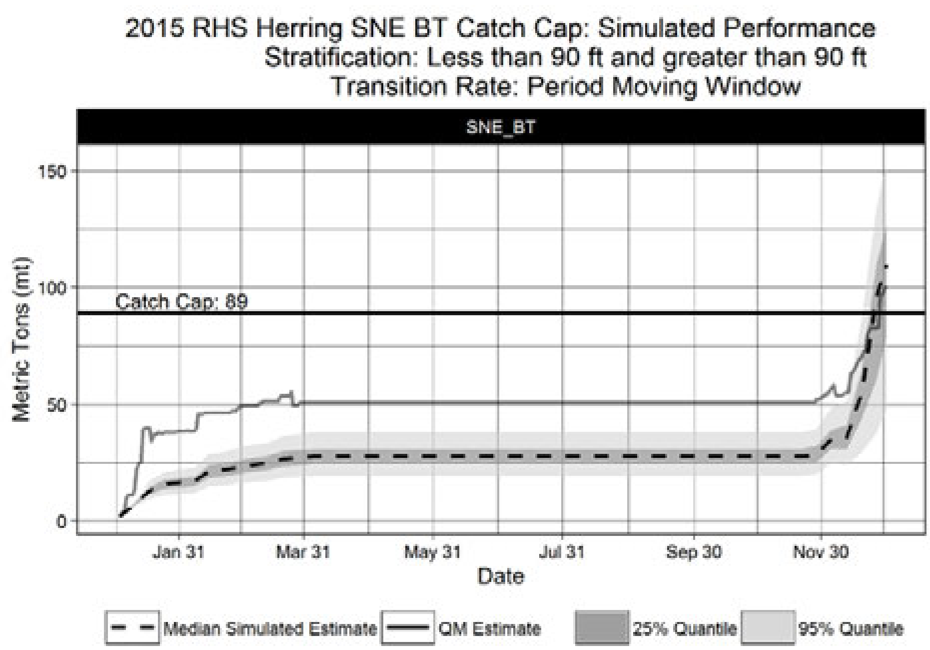

Figure 23. 2015 RHS herring SNE bottom trawl catch cap simulated vessel length category less than 90' and greater than or equal to 90' stratification alternative with moving window transition rate

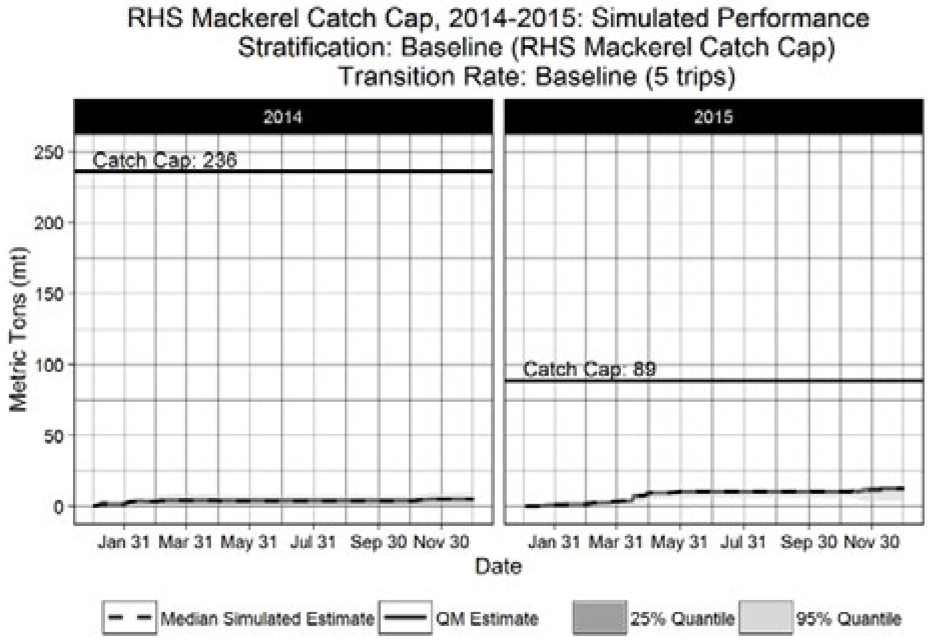

Figure 24. 2014-2015 RHS mackerel catch cap simulated baseline stratification alternative with five trip transition rate

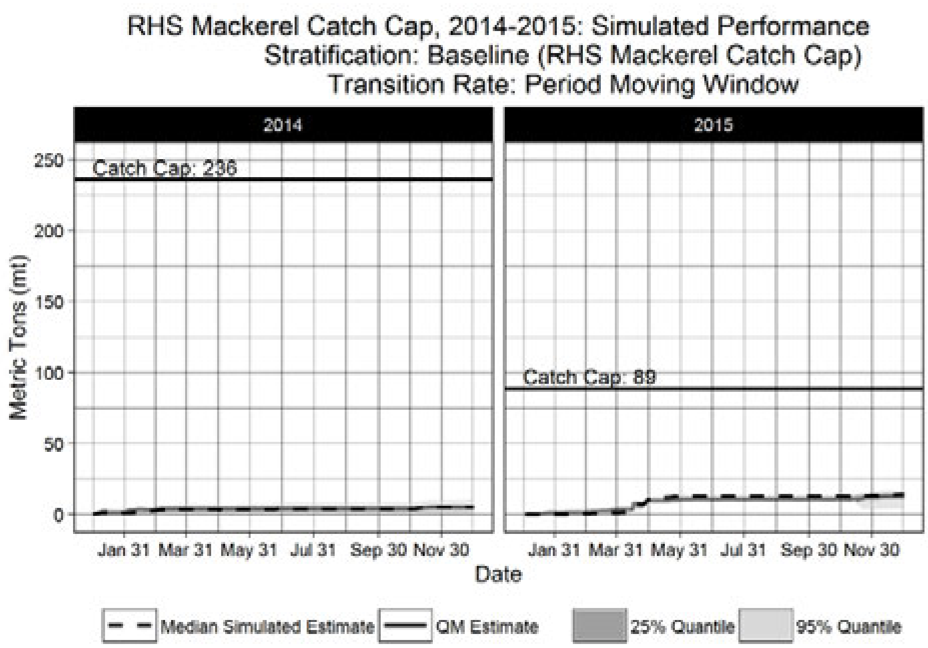

Figure 25. 2014-2015 RHS mackerel catch cap simulated baseline stratification alternative with moving window transition rate

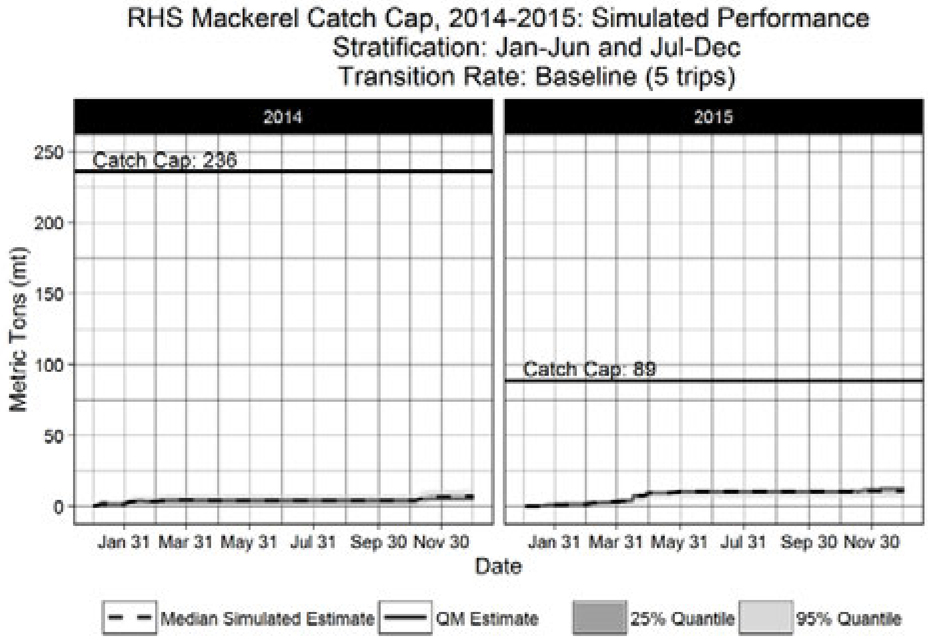

Figure 26. 2014-2015 RHS mackerel catch cap simulated half year (Jan-Jun and Jul-Dec) stratification alternative with five trip transition rate

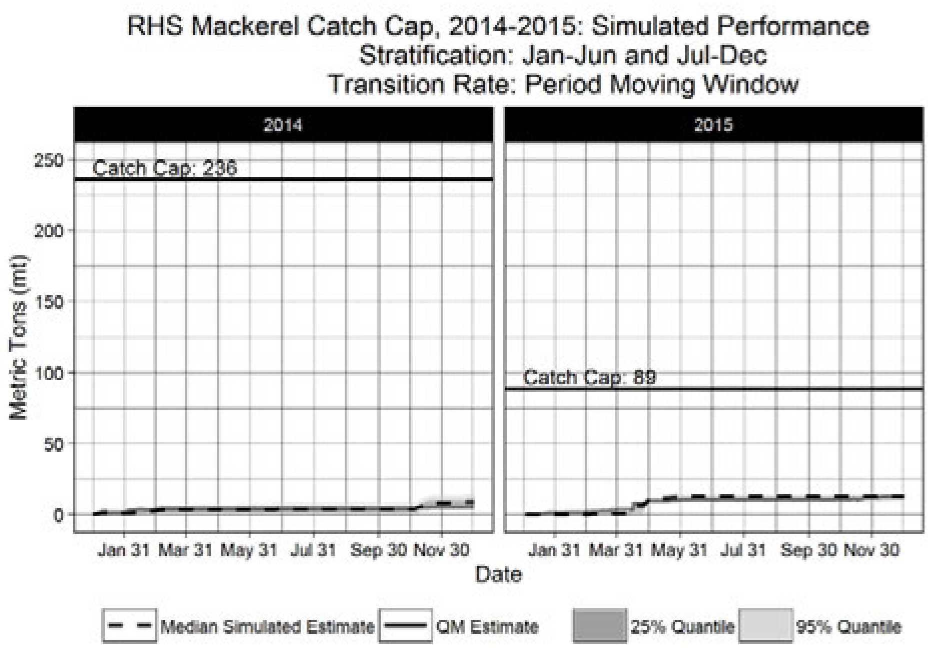

Figure 27. 2014-2015 RHS mackerel catch cap simulated half year (Jan-Jun and Jul-Dec) stratification alternative with moving window transition rate

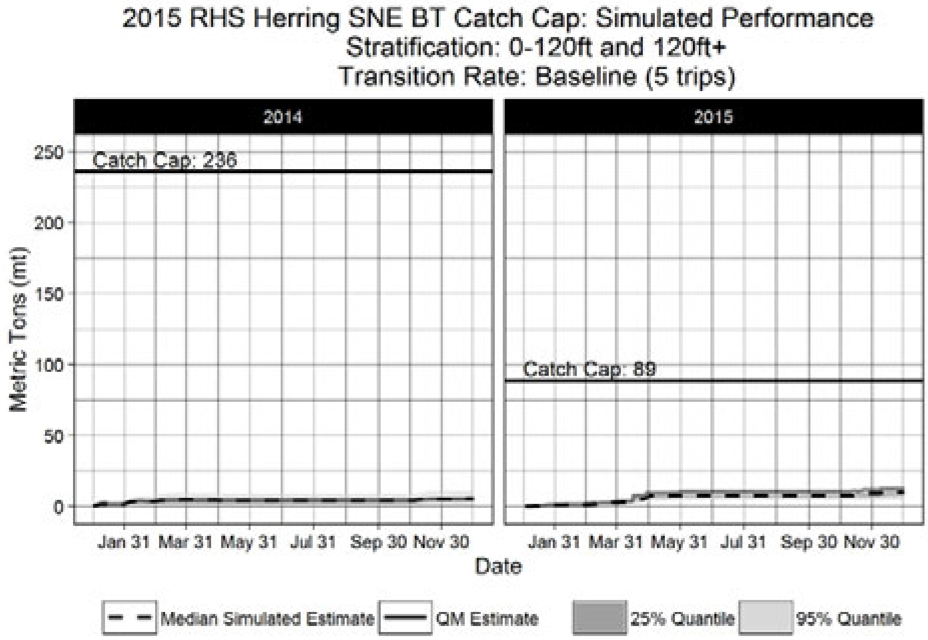

Figure 28. 2014-2015 RHS mackerel catch cap simulated vessel length category less than 120' and greater than or equal to 120' stratification alternative with five trip transition rate

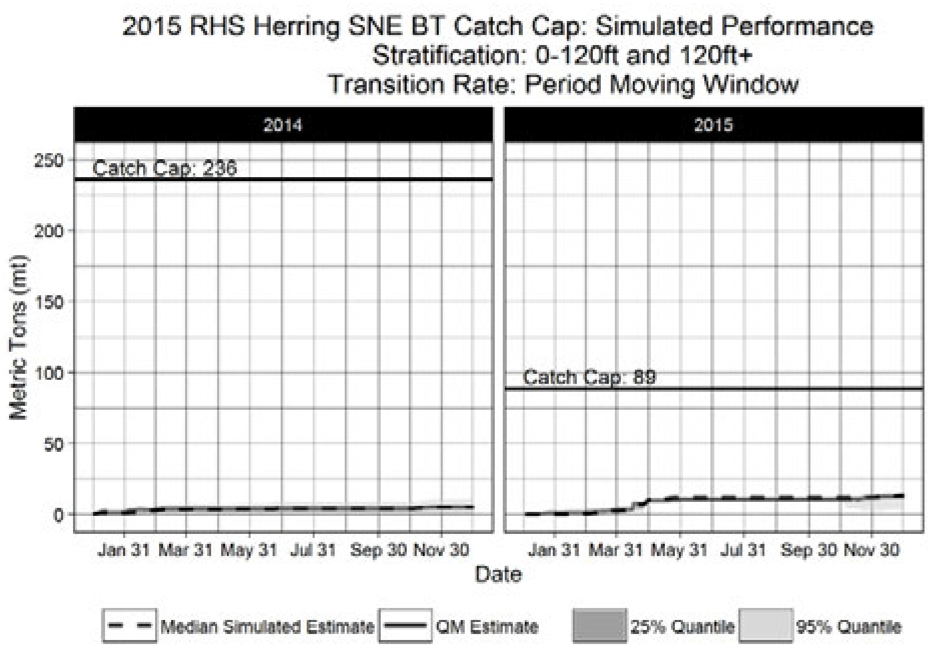

Figure 29. 2014-2015 RHS mackerel catch cap simulated vessel length category less than 120' and greater than or equal to 120' stratification alternative with moving window transition rate